A SMARTPHONE APPLICATION THAT INFORMS WEIGHT SHIFTING BEHAVIOR TO PROMOTE TISSUE HEALTH

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SUMMARY

One of the most persistent problems affecting wheelchair users is pressure ulcers. These are ulcers that wheelchair users develop in areas of constant pressure or interruption of blood flow to a localized area. Approximately one-third of patients who suffer from spinal cord injuries develop pressure ulcers, and it is a very expensive consequence for these people. Pressure relief exercises can help, but a high percentage of wheelchair users do not perform them enough.

Activity trackers today have the ability to sync with smartphone applications to monitor physical activity. The following study uses weight shifting behavior to help wheelchair users. By studying principles of usability engineering and user interface design, the researcher will design a smartphone application that pairs with a weight shift monitoring system to help promote tissue health. The application will illustrate information for the user to make them aware of their behavior and engage them in pressure relief exercises.

CHAPTER 1

INTRODUCTION

Over the last few decades, the number of individuals with restricted mobility has increased dramatically in major countries such as the United States, England, and France (LaPlante & Kaye, 2010; Sapey, Stewart, & Donaldson, 2005; Vignier, Ravaud, Winance, Lepoutre, & Ville, 2008). Wheelchair use is one of the suggested solutions for people with restricted mobility. Especially with the aging population and older adults, wheelchairs were chosen as one of the most important devices for their daily lifestyle (Mann, Llanes, Justiss, & Tomita, 2004). Wheelchairs, manual or powered, offer users increased independence and quality of life.

As new wheelchair users adjust to their new lifestyle and learn to perform daily tasks, they gain greater lifestyle options. Certain maneuvering techniques and exercises are taught to these users so that they get the most benefit from their wheelchair device. When used correctly, wheelchair use can help to modify the disablement process and reduce "the severity of the disablement." The users' social health can increase and they can participate in daily activities that allow them to be more independent. For example, those who are able to move around in a wheelchair demonstrate lower depressive symptoms than those who need to rely on others for assistance do (Krause, Carter, & Brotherton, 2009).

One of the most persistent problems affecting wheelchair users is pressure ulcers (Ferrarin, Andreoni, & Pedotti, 2000). These are ulcers that wheelchair users develop in areas of constant pressure or interruption of blood flow to a localized area (Novoa,

Calleros, & Merida, 2013). The ulcers tend to develop on the buttocks. Approximately one-third of patients who suffer from spinal cord injuries (SCI) develop a pressure ulcer, and it is a very expensive consequence for these people. In one study (n = 140), 33% of participants developed more than one pressure ulcer. There was a case of an individual having up to seven sores (Fuhrer, Garber, Rintala, Clearman, & Hart, 1993). Not only is it expensive for hospitals to treat pressure ulcers, but the patient might also be away from work and require post-treatment, which can in turn affect their mental health.

The development of pressure ulcers can be categorized into four stages. In stages 1 and 2, the sore can usually heal with non-surgical approaches. Cases at stages 3 and 4 lead to tissue damage and require surgery. Longstanding research has clearly demonstrated that the damaging effects of seated pressure are related to both its magnitude and duration (Kosiak, 1959; Reswick & Rogers, 1976). Prolonged loading on tissue is also associated with tissue deformation and cell death.

Based upon prior research, clinical interventions focus on addressing the issue via magnitude and duration of the sitting pressure. Pressure magnitude is managed by the selection of wheelchair cushions, other support surfaces, and body posture as one rests upon these supporting surfaces. Duration of pressure is addressed via the frequency of turning and weight shifting activities that actively redistribute pressure on the body surfaces (S. Sprigle & S. Sonenblum, 2011). Therefore, even though wheelchair cushions may help with comfort, posture, and weight redistribution, it alone cannot prevent pressure ulcers. Pressure relief exercises are proven to reduce interface pressure on the buttock and increase blood flow to that region (Sprigle, 2014).

Wheelchair users are suggested to learn pressure relief exercises because they prevent pressure ulcers by reducing the load time and duration of pressure (Stephen Sprigle & Sharon Sonenblum, 2011). To perform pressure reliefs, they are taught to lift the buttocks off the cushion surface, lean forward and/or lean to one side and then to the other. Guidelines have been published recommending that persons with SCI perform a pressure relief for 15 to 30 seconds every 15 to 30 minutes (Coggrave & Rose, 2003; Nawoczenski, 1987; Sliwinski, 2009). In-seat movement is very important, and pressure reliefs have been shown to greatly reduce the pressure on the sitting bones and increase buttock blood flow (Sonenblum, Vonk, Janssen, & Sprigle, 2014). Pressure relief exercises, therefore, are considered beneficial and should be followed by all wheelchair users.

Unfortunately, not all wheelchair users conform to the suggested pressure relief guidelines (Stockton & Parker, 2002). In Stockton's study, out of the 109 wheelchair users who responded as being physically able to perform a pressure-relief movement, 20.8% reported that they only moved once an hour and 54.7% moved less than once an hour. Self-management through today's assistive technologies may be able to provide low-to-moderate effectiveness in preventing pressure ulcer risk (Tung, Stead, Mann, Pham, & Popovic, 2015).

CHAPTER 2

OBJECTIVE

The objective of this project is to develop a visual interface for a smartphone application ("app") that informs wheelchair users about their weight shifting activity throughout the day, with the intention of influencing behavior change in the future. To meet this objective, 7 specific aims are proposed:

1. Review the current state of knowledge about activity tracking and its use to promote healthy behaviors.
2. Ideation of concepts that relay information about weight shift activities.
3. Develop and deploy an online survey and perform interviews with wheelchair users to obtain feedback on 5 visual interfaces that report daily weight shift activities.
4. Systematically evaluate the results and feedback from interviews and online survey.
5. Based upon feedback, select 2 concepts and using mock-up software, prepare these concepts for smartphone platform.
6. Perform a usability study with wheelchair users using the conceptual designs to report an example measurement of weight shift activity.
7. Evaluate the results from the usability study for a final design and develop 1 final design.

For the project to be designed in this thesis paper, the hardware associated with this study has already been developed. The hardware is comprised of four force-sensitive resistors (FSR) that send data to a custom data logger. It registers pressure reliefs as unloading of sensors lasting 15 seconds or more and weights shifts as movements lasting two seconds or more. Although the end goal of a product of this nature would be to influence behavior change, the hardware is not capable of delivering real-time data. Within the time-frame, the author of this project will only work on the visual display of information.

CHAPTER 3

BACKGROUND

One way that can be suggested to help wheelchair users follow pressure relief guidelines is to motivate them with their sitting habits and performance. This suggestion is based on the research that providing people with information of their performance is proven to improve their performance (Magill, 1985). Also described in Magill's book is motivating users with the knowledge of their performance. A more recent study using pedometers concluded that providing users with their performance can motivate their physical behavior (Bravata, Smith-Spangler, Sundaram, & et al., 2007). Perhaps showing wheelchair users their seating behavior can influence them to perform reliefs more often.

Pressure mats have been developed to sense and measure sitting pressure. Placed underneath a cushion, these mats consist of a matrix of pressure sensors. Pressure mapping is an effective and reliable way to measure a user's sitting behavior (Stinson, Porter-Armstrong, & Eakin, 2003). Pressure mapping can be used to determine a wheelchair user's seating surface, seating stability, and seating angle level to prevent pressure ulcers (Darlene Hanson, Pat Thompson, Diane Langemo, Susan Hunter, & Julie Anderson, 2012). Because it has been shown that there is a relation between interface pressure and the development of pressure ulcers, pressure can be used to indicate to the user when and where to shift the sitting load (Reenalda et al., 2009).

With devices today, monitoring physical activity has become affordable, and many people have turned to their smartphones to help them change a behavior. Over one billion people own a smartphone, and American Association of Retired Persons (AARP)

reports that "53% of those over the age of 50 are using or want to use some kind of health information technology in their mobile device." Currently, 20% of smartphones users have some type of health app on their mobile device (Greeshma K. Shetty & William Hsu, 2013). As for wheelchair users, there are a limited amount of applications designed for them. As of the writing of this paper, performing a search on the Apple App Store using the keyword "wheelchair" only results in applications that indicate wheelchair accessible areas and a database of wheelchair models (*Wheelchair* by J. Teunissen), aside from the assortment of games involving wheelchairs. Many lifestyle trackers and diabetes monitors exist to help specific users, and an app aimed at wheelchair users may also potentially be effective.

There is an opportunity for a new application, using wheelchair interface pressure data, to be an intervention method to encourage existing wheelchair users to shift positions in their chair and perform pressure relief exercises, geared towards reducing their chances of developing pressure ulcers. Specifically, with pressure ulcers, intervention has been shown to possibly help reduce the presence of pressure ulcers. *CareCall*, a tele-health voice response system, was tested with patients who used wheelchairs for more than 6 hours a day (Houlihan et al., 2013). *CareCall* used pre-recorded comments from professionals and vignettes to monitor and help the patient. There was a significantly lower incidence of pressure ulcers in women who received weekly automated calls from this system versus those who did not. Although *CareCall* used a phone call to deliver its service, its model can be applied to smartphone applications to create behavior change.

To design a smartphone application well, the field of human-computer interaction recommends certain guidelines to be followed. One of the first frameworks was called usability engineering. Usability engineering was originally explored by Jacob Nielsen in 1993. He discussed principles that designers should adopt to yield high usability for creating computer interactions. Nielsen defined usability as achieving the following: learnability, memorability, efficiency, error, and user satisfaction. He has clarified each point. Learnability is the ease of first time task completion; memorability is the ease of remembering steps for a task; efficiency is the time to perform a task; error is the number of errors a user makes; and user satisfaction is the subjective experience of the user (Nielsen, 1994). To measure the metrics of usability, Nielsen recommended prototyping, usability testing, interviews, and surveys.

Standards, such as ISO 9241, have been developed from this practice to set additional guidelines for designers. One section of ISO 9241, written in 1998, measures usability with effectiveness, efficiency, and satisfaction. Effectiveness is how well a user can perform the task accurately; efficiency is how quickly a user can perform the task; satisfaction is the degree to which users like the product (Mi, Cavuoto, Benson, Smith-Jackson, & Nussbaum, 2014).

With the rising popularity of smartphone application design, Nielsen's usability engineering principles were adapted for interfaces on smartphone applications. This became known as "simple design." At John Maeda's MIT Media Lab, simplicity became an area of research where he sought to understand the trend of "less is more" and to develop and refine principles of simplicity (J. Maeda, 2004; John. Maeda, 2006). Research by Blair-Early and Zender in the field began to define more concrete metrics to

measure user interface (UI) design in 2008. These researchers emphasized defining specific outcomes as opposed to vague definitions such as "easy-to-use" or "intuitive" (Blair-Early & Zender, 2008). Some examples of these were, designing an obvious start point, designing a consistent logic for content, and designing tangible responses to user actions. There were a total of 10 interface design principles that the researchers arrived at. Finally, according to the same authors, "it is clear that more precisely defined parameters for visual form are needed in order to apply design principles in measurable ways."

To help fulfill the goal of simple design, four principles have recently been used to measure UI design. These principles are reduction, organization, integration, and prioritizing. Reduction refers to designing a task to perform it in the minimum number of steps (Choi & Hye-Jin, 2012). Choi and Lee said it well when they said that, "Designers need to sacrifice functionality to offset the reduced steps in applications." Clear organization is creating layouts that minimize the cognitive load and allows the user to process information chunks efficiently. Integration requires various interface items in a system to be coherent across platforms and menus. Prioritizing means classifying and presenting functions by degree of importance.

Popular activity trackers on the market today, such as the Fitbit and Jawbone, have software included with their health tools that can link to a smartphone interface. Product services with a physical product and a smartphone application are beginning to show promise for public health interventions (Lyons, Lewis, Mayrsohn, & Rowland, 2014). Looking at previous work and benchmarking how information has been delivered will help support future design decisions.

CHAPTER 4

PRIOR ART

Physical activity trackers that have been invented in the past displayed and output information in various ways. The methods of display that were examined were aimed at different purposes including physical activity for athletes, recovery activity of amputees, calorie counting for obesity patients, blood sugar level for diabetes patients, and seating activity for wheelchair users. The aim of this research was to summarize the technology that has been used to present information and assess what has been previously successful. The research used the Google search engine, Georgia Tech journal database, United States Patent and Trademark office (USPTO), and Google Patent searches. Search terms used included "physical activity," "tracker," "obesity," "amputees," "pressure relief," "smartphone application," and "diabetes."

An early predecessor of the current activity monitors was patented by Texas Instruments Inc. (Barney, 1982). This device was made up of two parts. One device measured heart rate, velocity, calories used, and total heart beats, while a wrist-worn device displayed the information to the user. During the time that this device was released, physical exercise was becoming popular and many athletes began to put a high demand on their bodies. It was recognized that an athlete's heart rate needed to reach a certain threshold to derive benefits, but should not be too high because that can also result in adverse physiological effects. Therefore, this device had a way of notifying users, in the form of an audible alarm, when their heart rate became too high.

In 1990, a pedometer was patented that displayed information through a simple LCD display (Sutton & Noble, 1992). The device counted steps and displayed the information as large numbers that were easily read by middle-aged adults from two-three feet. These early activity trackers had limited technology and were able to display only a small amount of information on small screens.

Early physical trackers only gave one form of feedback. These devices gave a simple notification or alert in the form of a beep or a static text display. There were no interactive screens or devices that could track multiple metrics until fairly recently. In general, it seems that the type of feedback and display were related to the technology that was available at the time. As digital screen and sensors have become more advanced, the type of feedback has evolved alongside it.

Many companies have taken advantage of activity trackers' ability to keep track of heart rate, steps taken, and caloric expenditure (Thorndike et al., 2014) and marketed them as a tool to improve health and lifestyle (Heath et al., 2012). Although modern activity trackers are selling well, such as the *FitBit*, some users quit using the product because they did not understand the delivery of information (Cipriani, 2015). So, as much information as these trackers can collect, their success is ultimately determined by meaningful visualization of the data. The *FitBit* has been criticized for collecting information but not displaying it in a useful way (Samuel, 2015). The following will examine how information has been delivered in current products.

Major companies like *Fitbit, Nike, and Jawbone* have devices that connect users' daily activities and their physiological behaviors with a smart phone or web-browser interface. Figure 1 shows the home screen of these three apps. All three have a goal

setting feature that is displayed on the home page. The *FitBit* app seems to be aimed at the casual user and has a more neutral design. It has a horizontal bar that gets filled as the user moves closer to the goal. It lists the results in numbers on the home screen but the submenus show history in bar graphs. Its main purpose is to measure steps, so the application also lets the user know how many miles were traveled and how many minutes the person was active.

The *Nike +Fuel* app has a darker color theme and the progress is shown in a dynamic circular bar. The information is bolder and the app tries to promote other kinds of physical activity. The detail screen for daily information is shown as a line graph and the history is illustrated in short bar graphs. It also tells the user what percentage of the activity was performed during which phases of the day: late night, morning, afternoon, and evening. Lastly, the *Jawbone UP* app measure steps and sleep habits. *UP* shows the progress in bars on the home screen. The colors and animations can be interpreted as brighter and more cheerful. The home screen displays a scrolling feed of activity and accomplishments pertaining to the user. When checking history, this application shows

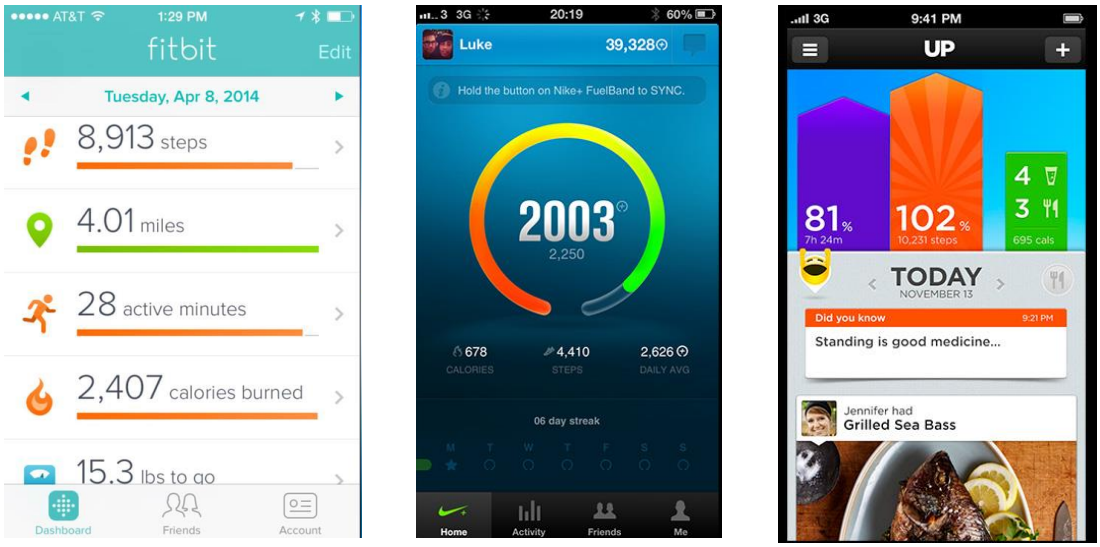


Figure 1: Home screens of *Fitbit, Nike +Fuel, and Jawbone's UP* apps

the information via bar graphs and lists supplementary numerical data on the same screen. These three are a sample of the many physical activity trackers on the market and all of them offer unique styles of display, interfaces, and experiences to the user (see Appendix A for more screenshots of apps).

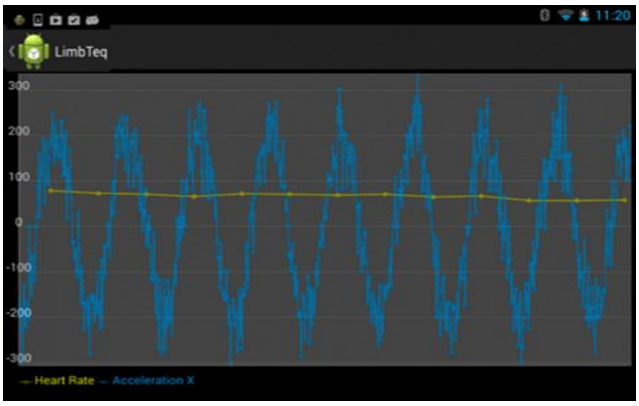


Figure 2: Screenshot of *LimbTeq* software

Pairing sensors with a smartphone application has expanded past physical exercise and into many medical uses. For example, activity monitors have been used by doctors for amputee patients to track their stride length, speed, and location during the day to ensure the patient recovers well (Hordacre, Barr, & Crotty, 2014; Tang, Spence, Maxwell, & Stansfield, 2012). The company *Barron Associates* has developed a system, titled *LimbTeq*, with a sensor that can be attached to lower-limb amputees that can display the physical activity of users in real time on an Android phone (Krepkovich & Hoover, 2011). The screenshot of the software (figure 2) displays the data in a line graph showing heart rate and acceleration in different colors.

Another area where smartphone applications are being used medically is to curb the growth of obesity. A proven method for obesity treatment is self-monitoring, which monitors the client's eating habits and gives them feedback on what they need to change from their diet (Nicklas et al., 2014). Applications such as *MyFitnessPal* help the client

log their eating habits during the day so they know what to adjust to lose weight. The screenshot of the *MyFitnessPal* app in figure 3 shows information in stacked bar graphs of different food nutrition, with numerical averages and goals underneath it. Each nutrition is a different color and the goal for the user is to keep it below a certain number. *Diabetes Pal* is another specialized app that shows diabetes patients their insulin and blood glucose level. One graph shows different vital measurements with a scatter plot and line graphs, while a pie chart shows the distribution of blood glucose ranges for a selected time span. Lowest, highest, and average blood glucose number for the selected time period is also shown.

Figure 3: Screenshots of *MyFitnessPal, Diabetes Pal,* and *Sensimat* apps

One of the earliest projects created to address pressure ulcers for wheelchair users was in 1968. In this invention, a pressure switch embedded in a mat was connected to a timer, power source, and tone-sounding device. To prevent decubitus ulcers, the tone would sound to alert the user to move. According to the article, this was the first device of its kind that actually trained the patient to perform pressure reliefs (Fordyce & Simons, 1968). Carr and Wilson, in 1983, conducted a study with one 34-year-old. They showed

that introducing feedback and informing the patient that they were being monitored increased the rate of pressure relief (Carr & Wilson, 1983). The aspect of informing the patient that they are being monitored can be adapted into a social aspect in the proposed application, where their information can be shared with other application users.

Recently a product under the name *Sensimat* and patent US 20110245732 A1 (Mravyan, Popovic, & Mravyan, 2011) was developed. It is a mat for wheelchair users to manage their sitting pressure and pairs with a smartphone interface. The interface helps the patient set alerts, track progress, and analyze trends in their pressure sore prevention. The screenshot in figure 3 shows information in a line graph and reports the number that has been done on the line. There are also different time spans that can be viewed.

The growth of smartphone use is very rapid. However, the use of health applications on phones, while popular, is still fairly new and few studies have been conducted to prove their efficacy (Bort-Roig, Gilson, Puig-Ribera, Contreras, & Trost, 2014). In order to target behavior change, apps tend to use some of the 14 behavioral change techniques (BCT) that have been identified as potentially effective. In a review that looked at 13 activity monitor devices, all the devices used the following BCTs: goal-setting, review of behavioral goals, feedback of behavior, self-monitoring of behavior, and rewards (Lyons et al., 2014). Social support and social comparison techniques were found in eight of the devices. Even though reports of using integrated technology to effectively prevent pressure ulcers is limited, one review recommended developing technology that supports multiple approaches similar to those used for other chronic conditions (Tung et al., 2015). Overall, mobile technology as a tool is promising, but no consensus of effectiveness had been drawn (Conroy, Yang, & Maher; Sharifi et al.,

2013). Some studies show that intervention was effective in changing behavior (Wijsman et al., 2013), while others say there was no significant change (Sharifi et al., 2013).

CHAPTER 5

METHODOLOGY

1. Prior to any ideation of designs and engagement with human subjects, IRB approval was obtained. The following inclusion and exclusion criteria were observed for this project in recruiting participants for surveys, interviews, or usability tests.

   Inclusion criteria: Participants who were selected were adults (male and female) over the age of 18 years old, must have used phone apps before, and were full-time wheelchair users. This study did not have an age cap because a majority of wheelchair users are of older age and their feedback was welcomed as well. The design of this project aims to make an intuitive interface, but some design choices were based on the premise that the user had some level of familiarity with phone apps. Therefore, to get more pertinent feedback, interviews targeted users who used phone apps.

   Exclusion criteria: This study chose not to recruit users under age 18 so that parental consent would not have to be obtained.

2. The first ideation stage consisted of sketching different interface wireframes (see Appendix B for first design wireframes). There were a total of 12 different themed ideas. Various interactions and ways to display the information were explored.

Aspects that were considered included how to navigate menus, displaying the time and date, placement of buttons, and new ways to visualize the data.

At the end of this stage, 5 concepts were selected for further development (see Appendix C for five narrowed concepts). These five designs had unique interfaces and methods of visualizations. They were picked because they could potentially best incorporate techniques of goal-setting, reviewing of behavioral goals, feedback, and self-monitoring into the next iteration. For each design a home screen and two detail screens were created. The home screens functioned as the main navigation page and displayed general information for the user. Home screens navigated to two detail screens, one for pressure relief and another for weight shifts. The detail screens displayed more information about both activities through graphs, visualizations, or text blocks.

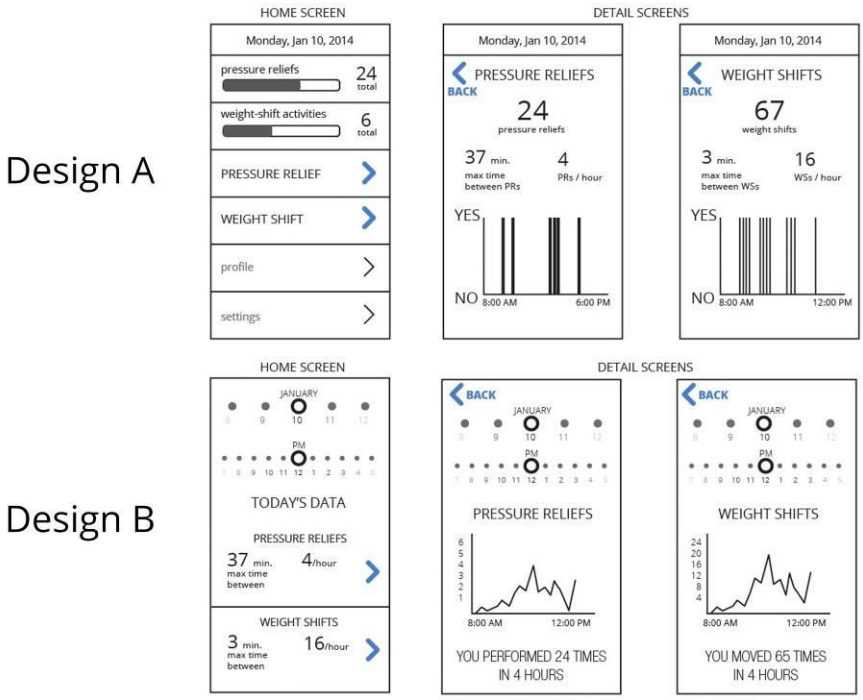


Figure 4: Screenshots of five initial designs for reference. Larger images in Appendix C.

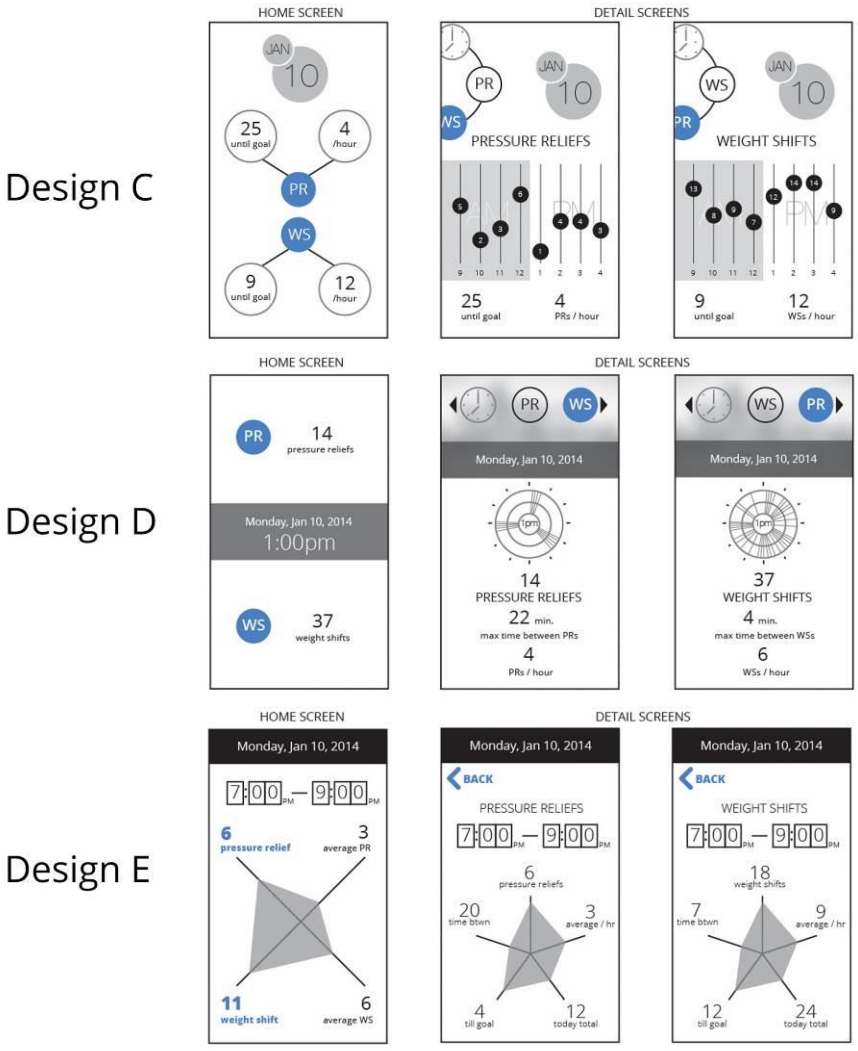


Figure 4 (continued)

The home screen for design A was split into six sections. The first two sections displayed goal bars for pressure reliefs and weight shifts. The daily totals were placed next to each bar. The buttons leading to the detail screens were placed under the goal bars, with an arrow next to the title to indicate an interaction point. The detail screens showed a discrete bar graph of the occurrences of each activity over time. The statistics stated on the screen were total, max time between instances in minutes, and average per hour. For both screens, the statistics were placed above the graph and the

activity title was placed above the statistics. At the top of the screen was the date, which could be changed by tapping on it. A back button was placed next to the activity title.

Design B had different statistics on the home screen: max time between instances, and average per hour. This design also used an arrow to indicate an interaction point to get to the detail screens. To change the date in this design, there were two slider bars at the top of the screens. One slider bar indicated the month and day, and the bar below it was used to select the time of day. The user would slide these bars in combination to change the date. The detail screens showed a line graph of the total instances of activity over time. Another feature was a statement telling the user their performance, such as "You performed 24 times in 4 hours."

Design C followed a circular theme and abbreviated pressure reliefs and weights shifts as "PR" or "WS" within a circular bubble shape on the home screen. The home screen stated the number until the goal was reached and the average per hour. In this design, the date displayed the month and date in two overlapping circles. On the detail screens, a scroll wheel on the side was used to navigate but this could not be tested because these were static images. The graph for the data was a variation of a bar graph. The number of pressure reliefs or weight shifts was written in a circle, which was aligned on the chart with the time that it happened. The chart was shaded to indicate AM and PM.

Design D had a minimal home screen with a large time stamp in the center. This home screen also had abbreviations but the full terms, pressure relief and weight shift, were written out under the total counts. The detail screens had a side-scrolling navigation bar at the top, the date underneath it, and a circular graph interpretation of the data. The circular graph was inspired by a clock. At the center of the graph was the hour it was measuring, and the moments of activity were marked around the hour. The statistics on the lower half of the screen were total, max time between instances, and average per hour.

Design E had a radar chart on the home screen showing statistics for pressure reliefs and weights shifts. The exact totals were written at the end of each line segment. The radar chart was meant to give a general view of how close the patient was to their goal; the further a point was from the center, the closer the user would be to his or her goal. The text also doubled as buttons to the detail screens. Time and date could be selected with a scrolling picker when clicked. The detail screens used the radar graph again to show five statistics: total between a selected time range, the average per hour, the total for that day, how many till the goal, and the maximum time between the actions.

Each design was unique, however, the researcher felt that the designs for home screens A, C, and D and detail screens B, and C would be more favored by users. Home screens A, C, and D presented the information in a vertical manner. It was believed by the designer that it would be easier to read the screen from top to bottom.

Contrast this with designs B and E. In design B the slider bars for the date took up space at the top of the screen and the text was grouped at the bottom. In design E the radar chart was placed between the statistics on the page and a connection needed to be made between the chart and the data stated. The designs in detail screens C and D were created as attempts at new visualizations. The researcher felt the graph in design C was easy to understand because it stated the number clearly. The graph in design D was expected to be a little hard to understand and might require an explanation for clarity. Detail screen B was expected to be preferred by people because it used a more recognizable line graph.

A survey was written to evaluate these five concepts as well as questions about other features (see Appendix D for survey). The survey served to help the researcher understand what were pros and cons about the initial designs and extra features that could be potentially added. Two questions (Questions 1 and 12) involved a ranking of the five home screens and detail screens. Rank 1 being their favorite and rank 5 being their least favorite. Ten questions (Questions 2-11) involved answering on a Likert scale of 1-4. Each set of designs had a pair of statements which respondents had to disagree or agree with on the scale (1: disagree; 4: agree). Six questions (Questions 13, 14, and 16-19) were yes or no questions regarding their habits and potential features. Question 15 was a multi-part question asking to pick how likely a feature would be used. The final questions (Question 20) was an opened ended question for additional comments.

3. The initial concept review involved two methods: a survey and interviews.

   The online survey was deployed and open between April 7 and May 7. The online survey service Survey Gizmo, was used to create the survey. Shepherd Center and disABILITY Link Atlanta were contacted for cooperation in deploying the online survey and distributing recruitment flyers (see Appendix E for recruitment script and full list of groups contacted).

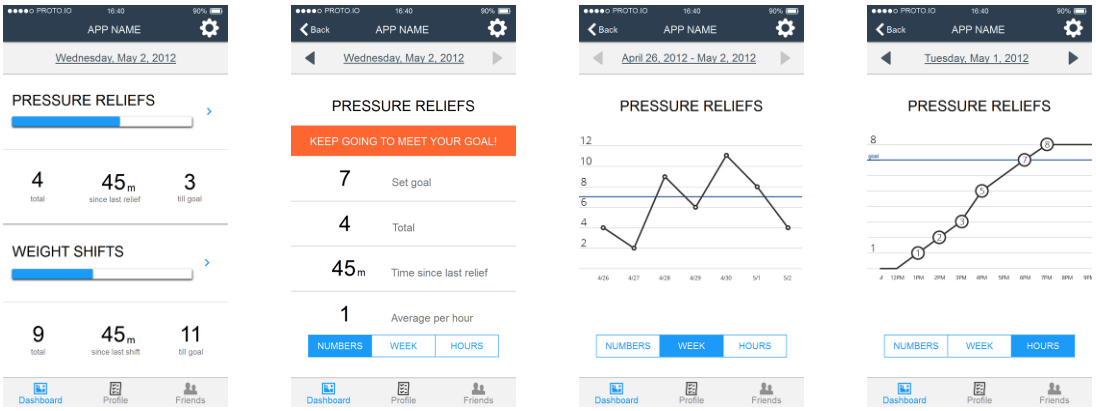
   Participants for the interview were selected according to the previously stated inclusion criteria. Eligible participants who were willing to volunteer sent a response to the investigator for this project who coordinated a follow-up with these people. Selected participants met the researcher at a location convenient for them. Interviews were conducted with five users.

   The interviews were scheduled lasting half an hour each (see Appendix F for full interview plan). Each participant signed a consent form before beginning the interview. They were asked to take the survey written in the previous step. Short questions and tasks were also asked after the study to obtain reasons for their chosen answers. Each participant was compensated $15/visit. Participants were asked to choose if they wanted to return for the usability testing portion of this study. If they chose to, they were told that they would be contacted when the next interview occurred.

4. The survey was evaluated by comparing the sum and mean values of results from each question, cross-tabulation using the pivot table option in Excel, and calculating the weighted score of certain answers (see Appendix G for full table of survey results). Both the online and in-person results were counted and totaled to help determine which designs to go forward with. The feedback from the interviews and any negative criticism were used to potentially modify the designs. Watching the participants helped determine user behavior and whether the intended design was successful or not. At the end of the analysis, two designs were selected for further development.

5. The second ideation phase iterated and refined the two chosen designs, design A-v2 (v2=version 2) and design D-v2, to a higher level of fidelity (see Appendix H for second designs). A color palette and icons were selected and designed to reflect the best clarity and information communication. A mockup software (Proto.io) was used to create the testable designs. The mockup was able to transition from menus and imitated what a real application would look and work like; ie menu interactions and navigation flow.

Design A-v2



Design D-v2

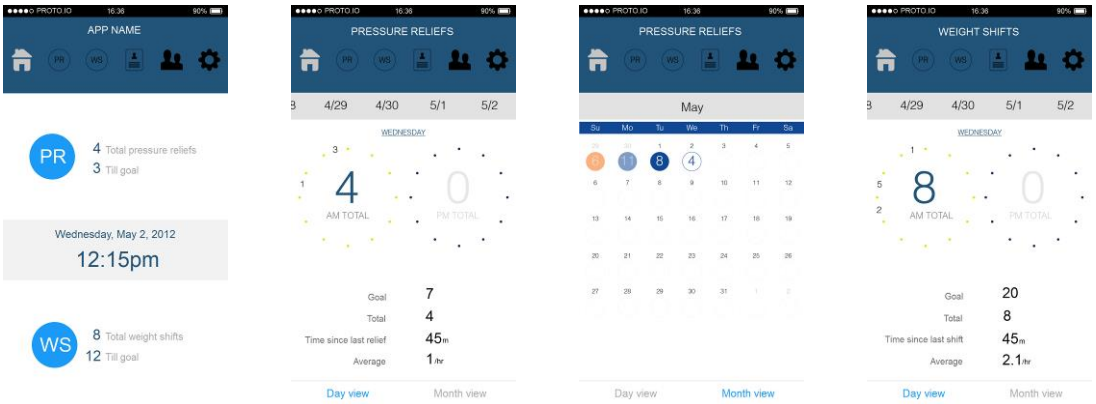


Figure 5: Screenshots of designs A-v2 and D-v2 for reference. Larger images in Appendix H.

Different features and menus were added to address the four behavior change techniques. Both designs had a goal setting function, but design A-v2 had a goal bar on the home screen and design D-v2 only stated the number till the goal was met. To review the behavior goal, each design had a method of viewing the history. Design A-v2 presented a graph with the goal line marked and design D-v2 showed a month view with the dates highlighted a certain color if the user reached the goal. The feedback screens on design A-v2 were separated into a graph screen and a statistic

screen. On design D-v2 the statistics and graph were on the same screen. The feedback data that was given were the number till the goal was reached, the average per hour since starting activity for the day, and the most recent time since last relief or shift. Lastly, the self-monitoring was the nature of the app in that it allowed the user to see their progress and history for themselves. In these iterations, a social network component was added because it was a technique that many existing apps utilized and suggested as effective. The researcher wanted to implement common and standard BCTs used in current applications.

An interview process was planned out (see Appendix F for usability testing plan), usability tasks were created, and a survey based on the constructs of simple design was written (see Appendix I for usability tasks and survey). There were 13 usability tasks. The first seven tasks asked the user to navigate the activity tracking portion of the app; i.e. the pressure relief screens and the weight shifting screens. They were required to navigate to a certain part of the app and interpret what the screen showed.

These tasks were:

- State how many pressure reliefs were done [two days ago].
- State how many pressure reliefs were done between 5pm – 7pm.
- Did you meet your goal?
- How many times did you miss your goal in the past 7 days?
- State how many weight shifts were done [last Thursday].
- State time since last weight shift.
- State how many weight shifts were done for [the current day] so far.

The last six questions referred to the rest of the features of the app: the social network, the training information, and personalizing the app. These tasks were:

- Check how many weight shifts [someone else did] today.
- Comment on [someone's] status.
- Watch a video on forward leaning pressure relief.
- Name one fact about pressure ulcers.
- Change the default name.
- Set a goal to perform 20 pressure reliefs today.

The tasks were measured according to ISO 9241 definitions: effectiveness, efficiency, and satisfaction. To measure effectiveness, the success of completing the usability tasks was tracked. Errors were measured as failure to complete the task. Effectiveness was a binary result, either "yes the task was completed" or "no the task was not completed." To measure efficiency, the time in seconds it took the user to complete the task was recorded. Timing would continue even if the user performed incorrect steps or went to the wrong menus. To measure satisfaction, a survey was given to the user after testing each prototype. The method of evaluation was adapted from previous research papers that used similar metrics to test mobile and web-based programs (Flavián, Guinalíu, & Gurrea, 2006; Moshagen & Thielsch, 2010). The participant were asked whether they agreed or disagreed with certain statements on simple design and usability.

6. With the usability tasks, a second round of concept reviews were done to test the 2 application mockups. Testing was done on a computer tablet or a smartphone device. With IRB approval, 10 participants were recruited from Shepherd Center who satisfied the inclusion criteria stated in step 1. Some participants were the same from

the first interviews and new participants were also obtained. The interviews were scheduled lasting 45 minutes each. Each participant signed a consent form before beginning the interview. Before starting the tasks, they were allowed to familiarize themselves with the app for two minutes by using it and navigating on their own. When ready, participants completed the usability tasks for each design separately. The order of which design was tested first was switched between participants to reduce the influence of being familiar with the tasks on the second design. Short questions were also asked after the study to obtain reasons for their chosen answers. Each participant was compensated $22/visit.

One user was selected to gather real data for the testing. He was given the pressure mat and his seating data was recorded for two days before the mat was collected. The data was analyzed and entered into the prototype apps for testing so that he could see his own data. This allowed for more personal testing and a realistic prototype.

7. The results were analyzed; the results of effectiveness, efficiency, and satisfaction can be seen in the tables in Appendix J. The true mean time differences between the order of testing and between the two designs were assessed within a 95% confidence interval. A final design, with color, layout, and other details finalized, was produced with the test results. This version was presented as a thesis project before a Georgia Tech School of Industrial Design review panel.

CHAPTER 6

RESULTS

6.1 First concept review results

The results of the first round of interviews and surveys were summed and calculated using completed surveys responses. Surveys were marked as completed if the respondent made it to the final page of the survey. Since the questions remained optional for participants, completed surveys did not mean that every question was answered. There were a total of 49 completed responses. The results were analyzed using total sums of answers as well as cross tabulation to compare different metrics (see Appendix G for full table of survey results).

Figure 6 and 7 show the weighted results of questions 1 and 12, which asked the user to rank the home screen and detail screens that were listed. The weighted score was calculated from the position that each screen was ranked at. Home screen for design A scored the highest with a weighted score of 169. Home screens B and D had the next highest scores of 145 and 144. The detail screens for design B and D were the top two designs with scores of 159 and 153, with design A having a score of 138.

Total weighted score of home screens in Question 1

Rank	*Weight score*	*Screen*
1	169	A
2	145	B
3	144	D
4	120	C
5	81	E
Total responses	47	

Figure 6: Results of Questions 1

Total weighted score of detail screens in Question 12

Rank	*Weight score*	*Screen*
1	159	B
2	153	D
3	138	A
4	132	C
5	97	E
Total responses	46	

Figure 7: Results of Questions 12

Results for Questions 2 to 11, which asked the respondent how much they agreed/disagreed on a scale of 1-4 with the statements “the information presented is clear” and “the information presented is useful” for each set of designs, are shown in figure 8. These words were defined by “clear” being easy to understand at first glance and does not take high mental effort to figure out what the design was showing. “Useful” was defined as providing the information that was important to each participant. For the analysis, Likert scale results were dichotomized with responses 3 and 4 indicating the screen was “clear” or “useful” and responses 1 and 2 indicating the screen was “unclear” or “un-useful.”

Designs A, B and D all had at least 66% of respondents marking 3 or 4 for clearness. Designs C and E had over 50% of respondents say the designs were 2 or 1, indicating it was unclear. For usefulness, all the designs, A, B, C, D and E, had between 60-70% of respondents say the designs were useful. Because all of the designs had around 60-70% of respondents say the usefulness of the designs were a 3 or 4, no clear conclusion could be drawn about the usefulness of a certain design. Cross tabulation of results had to be used to analyze the data more.

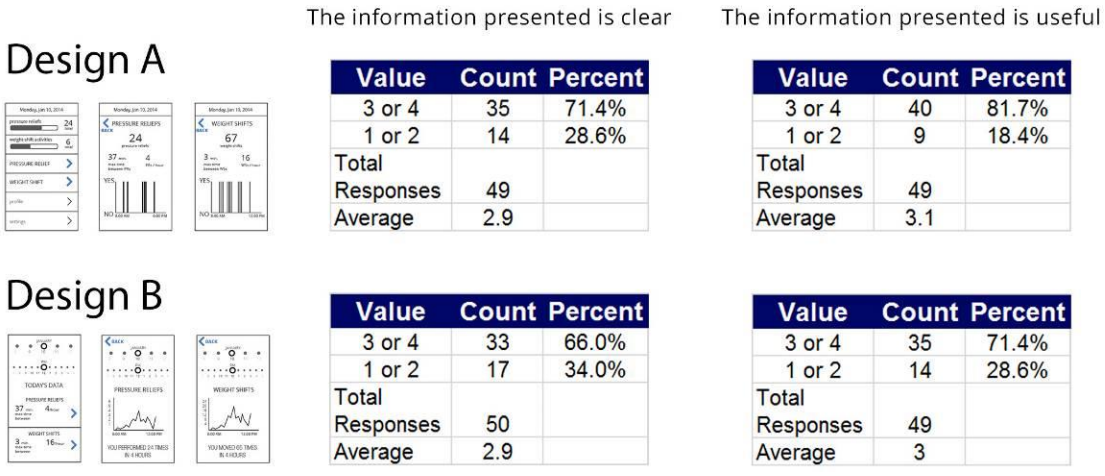
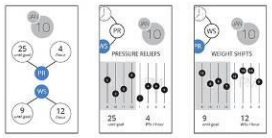


Figure 8: Results of Questions 2-11

Design C



Value	Count	Percent
3 or 4	23	47.0%
1 or 2	26	53.1%
Total Responses	49	
Average	2.4	

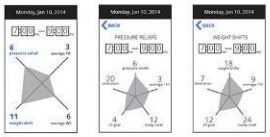
Value	Count	Percent
3 or 4	30	62.6%
1 or 2	18	37.5%
Total Responses	48	
Average	2.7	

Design D

Value	Count	Percent
3 or 4	34	69.4%
1 or 2	15	30.6%
Total Responses	49	
Average	2.9	

Value	Count	Percent
3 or 4	35	71.5%
1 or 2	14	28.6%
Total Responses	49	
Average	3	

Design E



Value	Count	Percent
3 or 4	17	35.4%
1 or 2	31	64.6%
Total Responses	48	
Average	2.2	

Value	Count	Percent
3 or 4	31	63.3%
1 or 2	18	36.7%
Total Responses	49	
Average	2.7	

Figure 8 (continued)

Although the data could be counted and observed, pivot graphs and weighing the rankings with different filters offered a more helpful analysis of results (see Appendix G for all pivot charts and the tables for weighed results). Two demographics which were used as filters were those who indicated as “regular smartphone user” and those who use health/fitness apps. Filtering out non-regular smartphone users was a more accurate example of the targeted end user. This application is designed to target users who have access to and are familiar with smartphones. The responses from both health/fitness app users and non-users was important. Fitness app users’ feedback was more reliable for what an app should look like since they have prior experience, but the sample size was small (n=13). Non-fitness app users constituted the majority (n=35). Their choice was also considered because the product should appeal to them to encourage them to use the app.

With these filters (figure 9 and figure 10), home and detail screens of design A, B, and D often came up favorably. On the other hand, for non-fitness app users, home and detail screens for design D were picked favorably, but still followed closely by designs A and B. Design C and E consistently had negative votes.

Weighted score of home screens in Question 1 w/ reg. smartphone users

Rank	*Weight score*	*Screen*
1	132	A
2	123	B
3	117	D
4	95	C
5	58	E
Total responses	35	

Figure 9: Results of Questions 1 w/ regular smartphone users

Weighted score of detail screens in Question 12 w/ non-fitness app users

Rank	*Weight score*	*Screen*
1	109	D
2	106	B
3	93	A
4	90	C
5	71	E
Total responses	35	

Figure 10: Results of Questions 12 w/ non-fitness app users

Figure 11 shows the results from Question 15, which asked how likely someone would be to use each of six suggested features. Results were dichotomized with "very unlikely" and "unlikely" into unlikely, and "very likely" and "likely" into likely. The figure shows the dichotomized number of people that picked each likelihood (see Appendix G for full table). Most responders would be likely to use the following:

- Setting goal to move a certain amount throughout the day
- Notification to prompt you to perform a pressure relief
- Weight shifting behavior history
- List of local recreational activities

These four features had a low number of people who selected unlikely responses. Two features that had higher unlikely answers than others were "Information on Pressure Ulcers," and "Pressure relief exercise instructions and videos." Because of this feedback, access to these features was more embedded within the next iterations of the app.

Task	Unlikely	Likely	Total responses
Setting goal to move a certain amount	15	34	49
Notification to prompt you to perform a pressure relief	12	36	48
Pressure relief exercise instructions and videos	22	27	49
Information on pressure ulcers	27	21	48
Weight shifting behavior history	13	36	49
List of local recreational activities accessible to wheelchair users	11	37	48

Figure 11: Results of Question 15

The results from questions 13, 14, and 16-19 are shown in figure 12. The majority of responders said they would be willing to connect, talk, or share their information if there was a social network aspect to the application. However, the majority said they would not be motivated seeing other people's behavior. Again, using pivot tables, users who were unwilling to connect with other users also tended to be less likely to message or talk to them. Regular smartphone users tended to be the opposite. 31 out of 40 were more likely to use the notification prompt and 27 out of 31 were likely to connect to other users. The target user for this application is smartphone users, so it was good to see the potential feature being validated.

13. Do you use a smartphone on a regular basis?

Value	Count	Percent
Yes	40	81.6%
No	9	18.4%

14. Do you use any health and/or fitness apps on your smartphone?

Value	Count	Percent
Yes	13	27.1%
No	35	72.9%

16. Would you be willing to connect to other wheelchair users through an app?

Value	Count	Percent
Yes	31	63.3%
No	18	36.7%

17. If you could connect to other wheelchair users, would you message or talk to them?

Value	Count	Percent
Yes	28	58.3%
No	20	41.7%

18. Would you be willing to share your weight shifting activities with others who also use the app?

Value	Count	Percent
Yes	28	57.1%
No	21	42.9%

19. Do you think it would motivate you to perform more pressure relief exercises if you saw how others were behaving?

Value	Count	Percent
Yes	23	46.9%
No	26	53.1%

Figure 12: Results of Questions 13, 14, 16-19

The 5 interview sessions helped gather more detailed responses. The feedback was more personal and the researcher was able to ask follow-up questions that allowed further insight and explanation to answers. All the participants were able to navigate from the home screen to the proceeding menus with relative ease and changed the date of the display as the designer had intended. After asking them to explain their survey answers, the researcher was better able to understand what might have been unclear. For example, design C consistently received poor feedback; one person said "the graph looks like guitar frets." When others were asked, "If they would be likely to use the pressure relief information and exercises option," many said that pressure ulcer information and relief exercises were topics they already knew and would not be something they needed to see again.

Some responses from the opened ended question at the end expressed their interest that the application should have an alarm or a notification for when to move. This suggested that the designs might have been unclear that there would be a notification system for the user to perform a pressure relief. As this is one of the main functions of the application, this concern would have to be addressed more clearly for the final design.

As mentioned before, designs C and E consistently had poor scores and feedback. Design C was intended to have interactions and visualizations that followed a circular design theme. It is speculated that the reasons design C was not considered "clear" were because the home screen did not have a clear indication of time and that there was no explanation for what the abbreviations "PR" and "WS" meant. The home screen of design E had the lowest weighted scores. The reason for this could be that the radar chart was unclear and hard to read. The radar chart also could not give exact values, so

although the values were stated, one could not use the chart itself to get exact information.

The screens for design C had 53% of people disagree with the statement “The information presented is clear.” This means that the majority thought the designs were unclear. From the interviews, the researcher discovered that the graph was not understood by many people. The numbers in the circle were meaningless without a vertical axis label, and the numbers along the bottom axis were also unclear. Detail screens for design E had 65% of people score it 1 or 2 for clear-ness. It can probably be said that the reason for this is because the detail screens also used the radar chart which were not effective in delivering clear information and difficult to decipher.

Overall, the participants seemed to favor a simple display but also valued having more traditional graphs and clear information. Designs A and D were chosen to move forward with. Design A was chosen because it ranked the highest among different metrics. Design D was chosen over design B. Designs B and D ranked highly in different measurements but design A and B were more graph-centered designs, and design D offered a more visual and creative direction that the researcher wanted to explore in the next phase. It was also noted from the interviews that that some people did not prefer graphs so a design with a different visualization, but one that respondents also favored, wanted to be used subsequently.

6.2 Second concept review results

The second concept review involved usability testing for design A-v2 and design D-v2, testing different interactions and methods of displaying data (see Appendix H for all screenshots of the designs). 10 users tested each app once and were timed upon completing each of 13 tasks. The method of analysis was based on the three measures of usability: effectiveness, efficiency, and satisfaction.

During the testing, with respect to effectiveness, there were two tasks where two or more users failed to complete the task. The two tasks were:

- 1e: State how many pressure reliefs were done between 5pm – 7pm
- 1h: How many times did you miss your goal in the past 7 days?

The first task required the user to interpret a graph to state how many pressure reliefs were done between a given time period, and the second required the user to interpret another visualization and state how many times a goal was missed within the past week. For Design D-v2, seven people failed task 1e and three people failed task 1h. For Design A-v2 only one person failed each of those two tasks. The only other instances of failures were the tasks “Comment on their status” (Question 3d) for design A-v2 and “State time since last weight shift” (Question 2e) for design D-v2. Both of these failures were committed by the same user.

A measure of time, in seconds, was used for efficiency (see Appendix J for a complete table). First to assess if the order of the presented design had an effect on the final result, the time differences between the first and second app given to the participant were compared against each other. It was expected that the second test would perform

with faster times since the participant will have been familiarized after using the first application. The resulting analysis showed that for 95% of the tests, the overall time for the first app that was given was between .15 and 6.3 seconds slower than the second app. Between the times for design A-v2 and D-v2 overall, design D-v2 was between .76 and 6.7 seconds slower 95% of the time. Figure 13 shows this distribution.

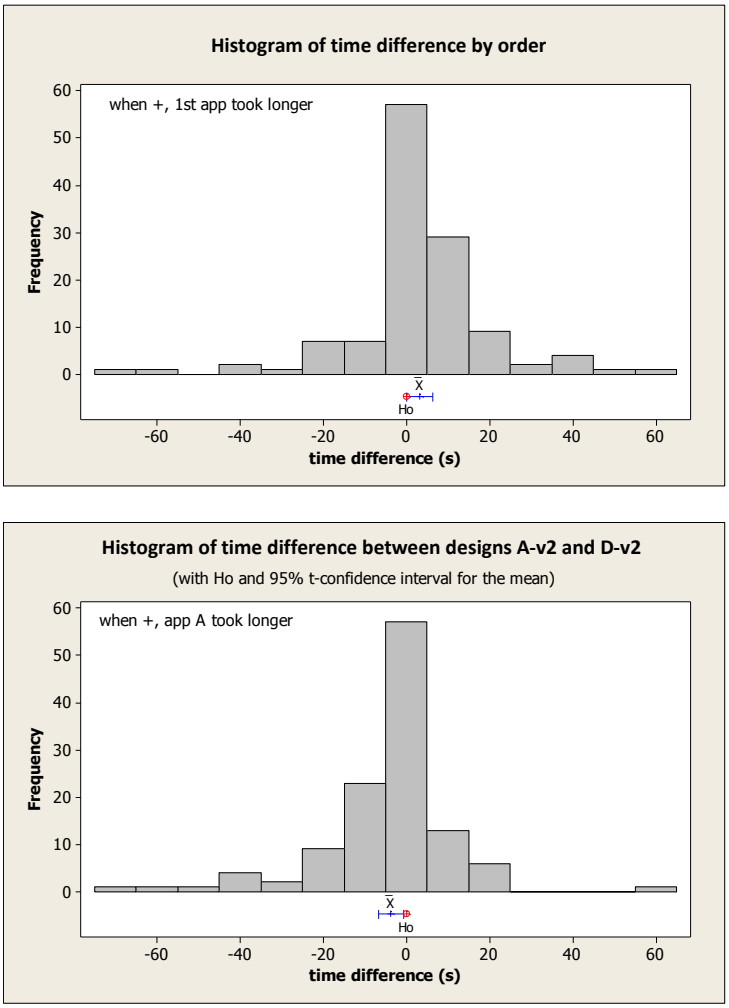


Figure 13: Histogram of time differences

Regarding each individual task, some tasks were distributed evenly between the two designs, while some appeared slower for a certain design. Figure 14 shows the distribution of time differences. Each point represents a person. A point above zero

means that the person was slower with design A-v2, whereas below zero means they were slower with design D-v2. Tasks with a wide spread signify that the times between subjects differed greatly, while smaller grouping of points mean that most subjects performed it within the same amount of time. Most tasks had points that are spread above and below zero, signifying that some people performed tasks faster with design A-v2 while other were faster with design D-v2.Points were only included and used in the figure if both tasks were successful, which is why task 1e has such few points; many people failed that task (State how many pressure reliefs were done between 5pm – 7pm).

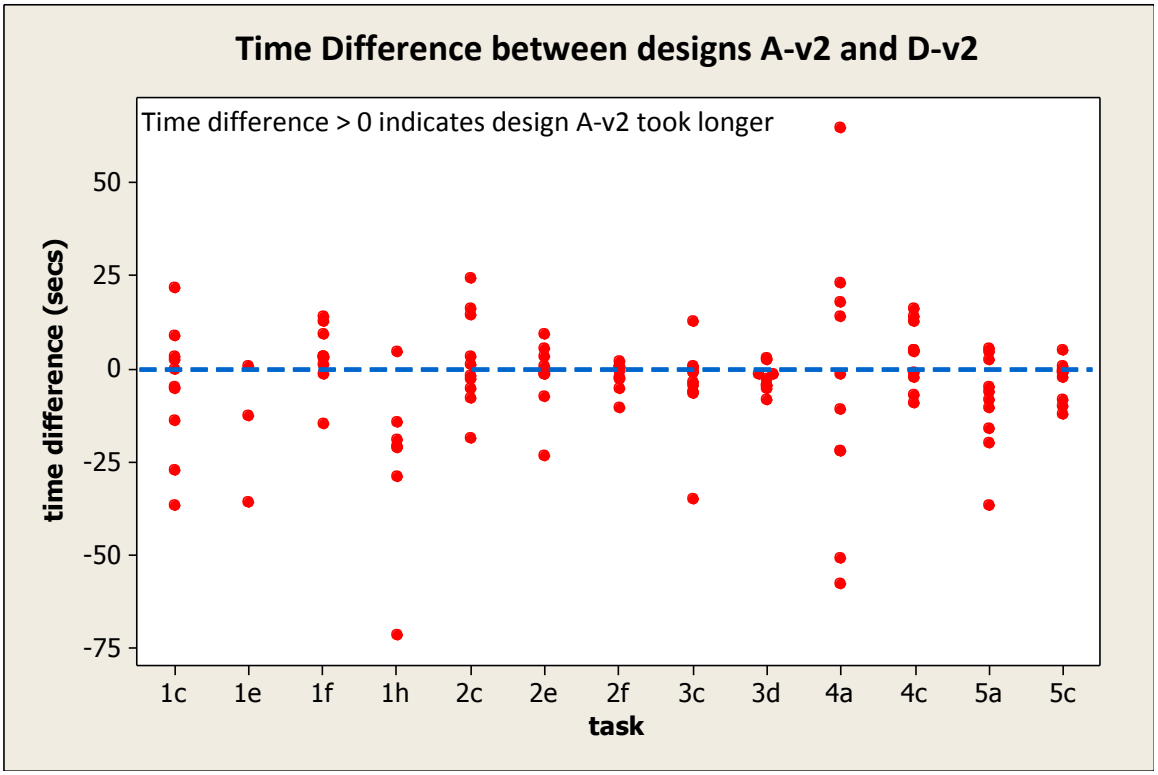


Figure 14: Plot of time differences between designs for each task

The tasks that were performed more slowly with design D-v2 were:

- 1h: How many times did you miss your goal in the past 7 days?
- 2f: State how many weight shifts were done that day so far.
- 3d: Comment on their status.
- 5a: Change the default name.
- 5c: Set a goal to perform 20 pressure reliefs today.

The tasks where Design A-v2 could be considered slower, but not confidently, were:

- 1f: Did you meet your goal?
- 4c: Name one fact about pressure ulcers.

The results from the satisfaction surveys (see Appendix J for survey results) did not lead to any direct changes in the design but helped to reinforce results that were shown through the efficiency and effectiveness measurements. Statements were viewed as undesired if the answer chosen was different from what the designer had intended the design to be like. The statements were written in a way to assess the design based on the constructs of simple design. There was a desired response that each statement was meant to elicit.

The questions with the most undesired answers were:

- 1. The app has unnecessary steps to use certain functions
- 2. The app has difficult steps to use certain functions
- 3. The app has functions I don't want
- 7. The app shows menu categories systematically

The satisfaction results were useful through the interview process because the researcher was able to ask the participants questions regarding their answers. For example, many people disagreed with the app having unnecessary steps to user certain function. Reasons that people gave were that they did not like how the app went back one day at a time with design A-v2, getting back to the current day was slow one with design A-v2, and viewing the month was troublesome with design D-v2. Another statement that participants disagreed with was that the app had functions they did not want. When asked if they could specify, most participants said that they did not expect to use the social or training aspects, but at the same time, most of them mentioned that these would be useful

features for new users. Their responses also explained how they thought the placement of the training menu was unintuitive.

More people gave more undesired answers for design D-v2 versus design A-v2. Out of the ten participants, seven people gave more undesired answers with design D-v2 than they did with design A-v2. Two people gave the same amount of undesired answers for both designs. Therefore, only one user gave design A-v2 more undesired responses; this was the same user who was the subject to fail at two tasks where no one else failed.

Figure 15: Screenshots of final design for reference in the following chapter. Larger images in Appendix K.

CHAPTER 7

FINAL DESIGN

The final design uses the results from the second round of user testing and combines elements of both (see Appendix K for final design screenshots). Visual and design aspects were taken from design A-v2, and navigation and layout elements were taken from design D-v2. These decisions were based on the results of the measurements of effectiveness, efficiency, and satisfaction from the user testing. According to each construct, design A-v2 was performed more correctly, in a shorter amount of time overall, and satisfied more users.

Reading the visual displays and interpreting what was shown on the screen was not only faster with design A-v2, but more successful. Important tasks, such as stating a value between certain hours (task 1e) and stating how many times a goal was missed over the past 7 days (task 1h), were slower and less successful with design D-v2. Figure 16 shows the screens associated with these tasks. With the measure of effectiveness, 7 users failed to read the visualization and interpret instances between certain hours (task 1e) in design D-v2. Design A-v2 only had one user fail. This was enough evidence to favor design A-v2. The confidence interval for this task might have been spread between both designs (figure 14), but it was not reliable because so many users failed to interpret design D-v2. Additionally, when users had to state how many times a goal was missed (task 1h), all the times for design D-v2 were slower and 3 users failed, versus one user who failed to read design A-v2. Therefore, according to the measures of effectiveness

and efficiency, the visualization and month view in design D-v2 were abandoned for the final design.

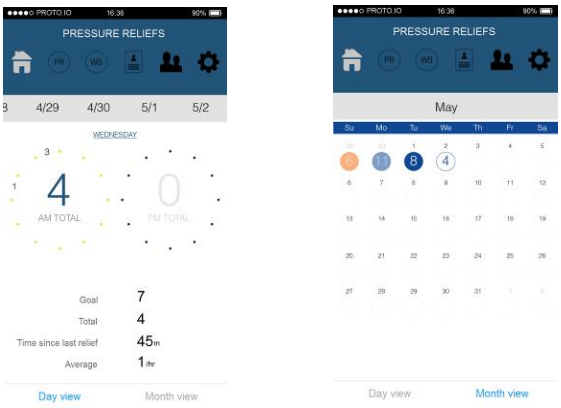


Figure 16: Screens from design D-v2 that had failures.

The designer was aware that there would be a learning curve with design D-v2 because it was based on a unique visualization resulting from the first iteration of designs. Even though the learnability of this design was harder, some participants explained that after learning how to read the visualizations, it was easier to understand and interpret. One step that could have potentially added more feedback was asking the users to test the apps over a prolonged period of use. This could also test for memorability or repeatability pertaining to each design.

Areas where design A-v2 suffered were navigation issues and layout issues. For usability task 1f (Did you meet your goal?), between the two designs, design A-v2 was almost always performed more slowly. This delay was because the graph and the textual information were separate and required the user to navigate and read the graph. With design D-v2 the goal was stated clearly on the same page as the graph. Because this task would most likely be repeated often, it made sense to choose the design that was faster. Adding an additional improvement, the line graph in design A-v2 was also used on the screen to give readers another method to glance at the screen to see if their goal was met.

For this reason, the final design combines both the graph and textual information on the same page.

Design A-v2 used mainly arrow buttons to navigate, whereas design D-v2 used more swiping motions. Again, looking at figure 14, the confidence interval for the task of asking the user to go back a week in the past (task 2c) was evenly distributed between both designs. However, during the interviews, the researcher noticed that two of the wheelchair users had limited dexterity in their fingers. They had learned to compensate for their limited dexterity by pressing the interface buttons with their knuckles. Even though the users performed both tasks within the same times, the swiping motion could potentially be easier for them to use and was chosen. This aspect would have to be tested more in order to be proven.

In order to follow the reduction and integration goals of simple design more closely, some of the icons on the navigation bar from design D-v2 were removed. To switch between checking pressure reliefs and weight shifts, the user would have to go back to the dashboard. This reduced the number of redundant options and steered the user in one direction. The month view was taken from design D-v2 and integrated with design A-v2. An option to select a range from a calendar would pop up if the date was pressed (figure 17). After selecting the range, a graph of the week view would be shown. This option was considered because it adds an easier navigation method without adding another button onto the navigation bars. The settings option would always stay in the corner of the application to ensure it would be accessible within one step.

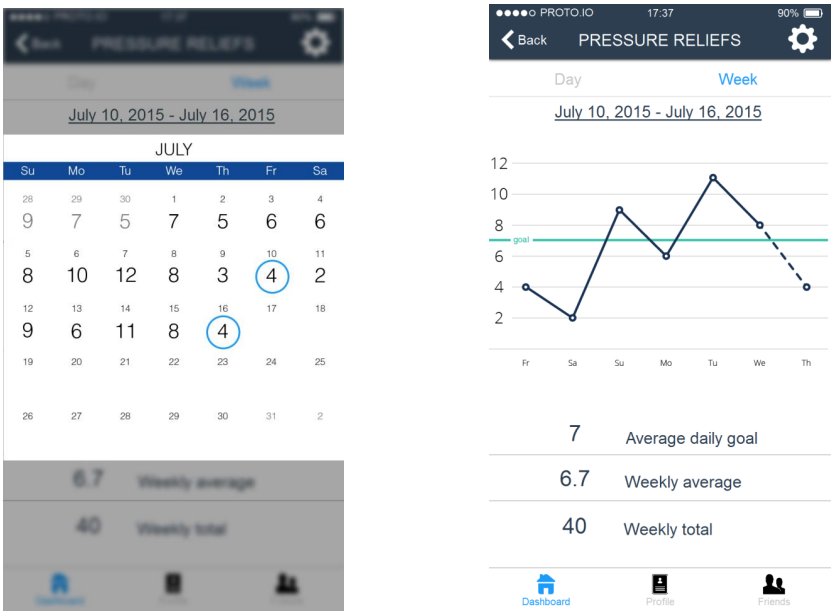


Figure 17: Final design screen of selecting a week view

The abbreviations “PR” for pressure relief and “WS” for weight shift was removed because some users said they did not know what it stood for and that it could be vague without instruction. For the final design, the full term was written out but the circular, blue button was kept to indicate to the user what to press to go to the next screen.

Many participants during the second round of user testing stated that the social network would not be something they would use, but they said it would be something new users might find beneficial. The participants in the second round were experienced wheelchair users who knew about pressure reliefs or were regularly performing them anyway. Their responses were considered bias. For the final version the designer chose to keep the social network aspect because the initial survey indicated that people were willing to connect to other users. Another reason is because it is anticipated that newer users would use this app.

CHAPTER 8

DISCUSSION

There were 12 initial wireframes in the beginning of this study. Five of the strongest concepts were picked out to be included in a survey. When the survey responses were returned, tables and charts were created for the total responses and with filters for regular and non-smartphone users, and fitness and non-fitness app users. Viewing all the responses, home screen for design A had the highest weighted score of 169 and detail screen for design B had the highest score of 159. Regular smartphone users yielded the same screens, home screen A and detail screen B, as their top choice. However, for non-fitness app users, design D's home screen and detail screen had the highest weighted score, 99 and 109. All five designs had approximately two-thirds of responses say the detail screens were useful. This did not aid in supporting conclusions. The even outcomes may indicate that the information the screened displayed were too similar and were not differentiated enough.

Designs A and D were then selected and expanded upon, into design A-v2 and design D-v2. Prototyping functional designs allowed more in-depth feedback and the ability to test for effectiveness, efficiency, and satisfaction. Results of the usability testing indicated that each design had particular strengths and weaknesses. The final design attempted to answer these problems within the framework of simple design.

In this research project, there were compromises that arose that affected the outcome of each stage of the design process. There were challenges the researcher faced, such as aiming for at least 50 responses for the survey. This delayed the process because

multiple people and interest groups had to be contacted to recruit enough avenues of survey distribution. The response rate was still fairly low and this may have affected the results from the surveys.

Another factor that was learned was that some of the questions in the survey may have been unclear; this issue was discovered during the interviews. Releasing these questions online left the interpretation of the question up to the survey taker. The results could have been skewed this way. There was also a selection bias for the usability test subject. The participants were recruited from Shepherd Center, a leader in spinal cord injury rehabilitation. They had more knowledge and expertise than average wheelchair users. While their answers and feedback were helpful, the average use would most likely not be as comfortable with the app as the participants.

This project reinforced the fact that design decisions cannot be made arbitrarily and need to be backed up with reasoning and data. Being able to test each iteration with different methods of gathering data was important because each method revealed helpful information. In the first stage of design, the online surveys was focused on gathering a quantity of results. The interviews juxtaposed the results with more thoughtful feedback and responses to why answers were chosen. During the second user testing stage, watching the participants showed that users would interact with the prototypes in ways the designer did not expect. Whereas one users would read the graph to fulfill a task, another went to the homepage to get the answer. Observations also showed that some users had limited dexterity, which influenced the direction of the final design.

Ultimately, the goal of the application is to encourage behavior change and this application could not test that. It did, however, attempt to use certain BCTs that were

recommended for helping prevent pressure. The final design used the following BCTs: goal-setting, review of behavioral goals, feedback of behavior, self-monitoring of behavior, and social comparison. The goal setting feature was used because it was shown to be an effective technique for behavior change (Lyons et al., 2014) and since the first survey indicated it would likely be used by users. The app allows the user to review their behavior goals by checking how often they hit their goal within the past week. Ideally the user would aim to hit their goal every day. The application would also give users an alert, through a buzz or message, if they need to move more to meet their goal (figure 18). This feedback of their lack of action is a reminder to get them to perform the correct behavior. The home screen was designed for easy and quick readability so that the user can self-monitor their behavior. One design improvement for the next iteration could be to send push-notifications from the software so the user could see their progress on the app's icon on the phone's home screen so they would not have to open the app at all.

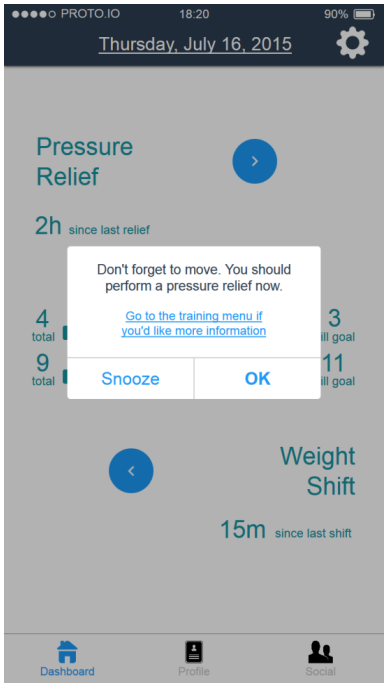


Figure 18: Alert message in final design

One of the top BCTs that was also recommended that this app did not utilize was a reward system. The next iteration can have animations or an achievement system that celebrates the fact that the user has met his or her goal. This could potentially encourage them to change their behavior as they strive for the reward. A future step for this project would be to test the application and see if it can be effective in changing pressure relief behaviors. Figuring out which behavioral change technique is more effective is also equally important. Depending on whether the goal setting, feedback, or self-monitoring feature help users the most, more emphasis can be put on improving those designs.

The development of this project was based on building on previous design phases and iterations. It would have been interesting to see and compare the final design with the same usability tests used for the second round of user studies. The social network component, also, would have to be tested to see if it can work successfully. It is based on the premise that enough people use the app and are willing to share their information and connect with other users. If not enough people use the social network, it will be inactive and fail to motivate other users.

This paper may serve as a tool if this project is to be continued or if a similar product is built off these designs. Future iterations should consider designing improved usability, menu flows, and layouts. Some features that were considered in the first design wireframes were a vertically scrolling interface and having tiles of data and graphs on the home screen. Ultimately, these designs were not chosen, but the designs could be used for inspiration. There are also many other options to experiment with for displaying the data. Different bar graphs or layered charts are two examples. Bar graphs are popular in existing applications so they are certainly viable. Other ways to implement the behavioral

change techniques should be explored, such as approaches to goal setting or relaying behavior history. The benefit of swiping as navigation and animations as rewards should also be confirmed. In conjunction with the design, it is recommended that user testing be done soon after each design phase so that feedback can be obtained for improvement.

User interface mockup software is fairly new. The software used for this project (*Proto*.io) was effective and is recommended. It allows the presentation of different transitions, interactions, and animations. The software also allows testing through a browser or on its smartphone app, both of which the researcher used. However, other software such as *axure*, *Origami*, and *Framer studio* exist and the researcher encourages the use of these to see how they compare to *Proto.io.*

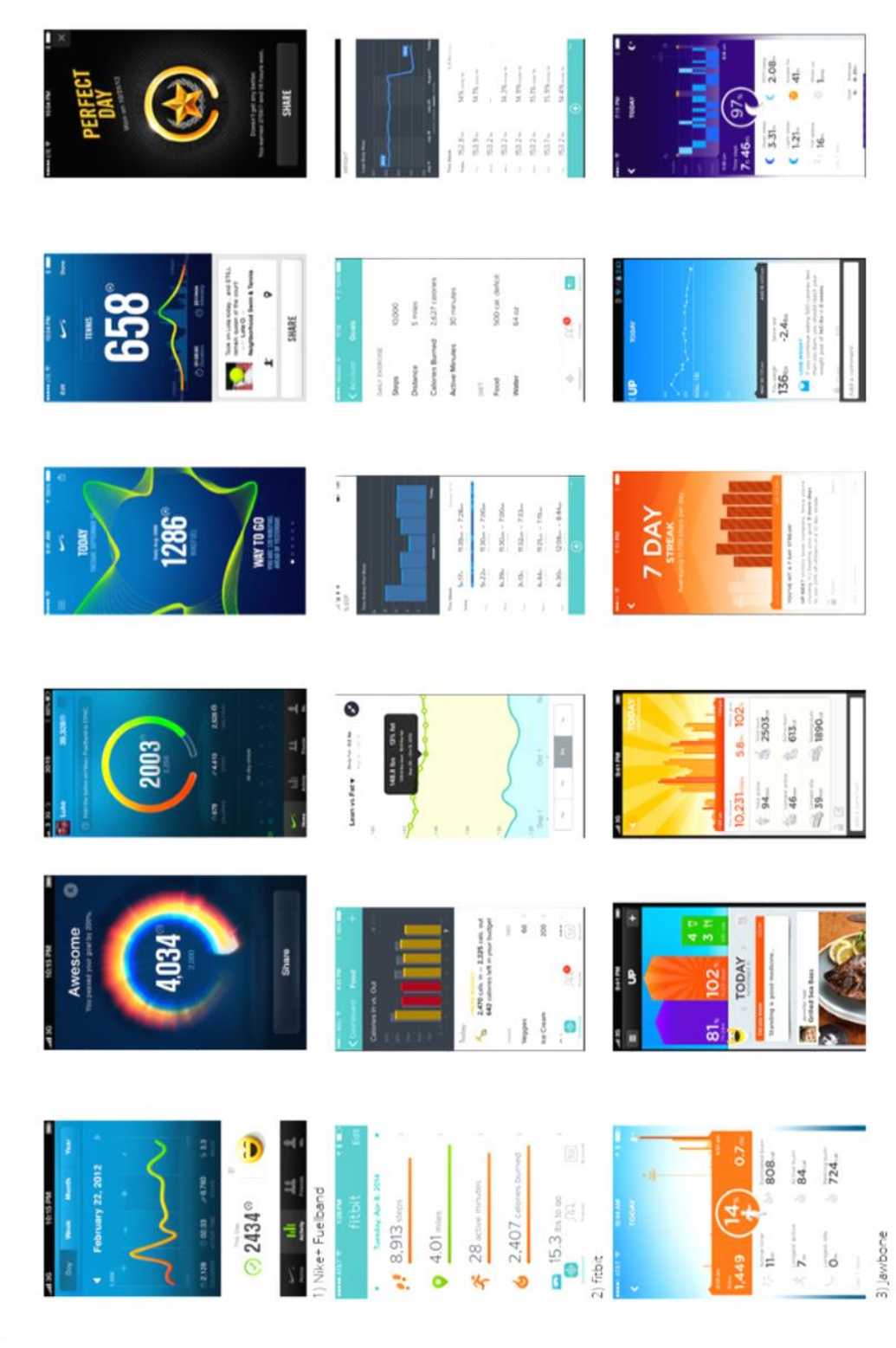
Components of the application that also need to be researched in further detail are designing for certain phone platforms, screen sizes, and for the audio and visually impaired. Typically, applications on Android and iOS differ slightly in their design and usability. This application was designed with the intention of usability on iOS, but a version for the Android phone can also be designed. Although the usability testing did not encounter any problems visually or with text size, it is something that needs to be considered so that the app is accessible to the most users.

The final design is the result of multiple iterations of design and research. Throughout the project, design decisions were backed up with research evidence as much as possible. The researcher tried to make each decision based on measureable metrics such as the number of survey results or using a measurement of time to indicate a better choice. There were also points when the researcher also had to make design decisions based on his knowledge and observations. The final iteration is an example of a

smartphone application that attempts to stay true to the goals of simple design, paired with a hardware component, designed to help a user improve his/her quality of life.

APPENDIX A

Screen study of existing products






4) Argus



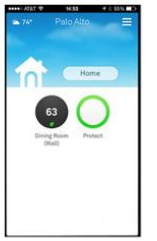
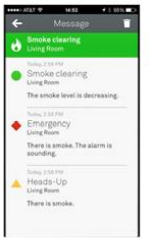


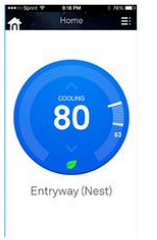
5) Withings



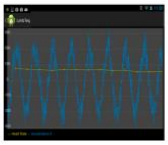
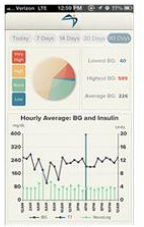



6) Polar H7



7) Nest

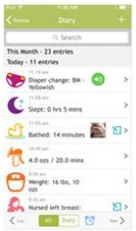

8) Limbteq

9) Diabetes Pal

10) Sleepio

11) Fjuul





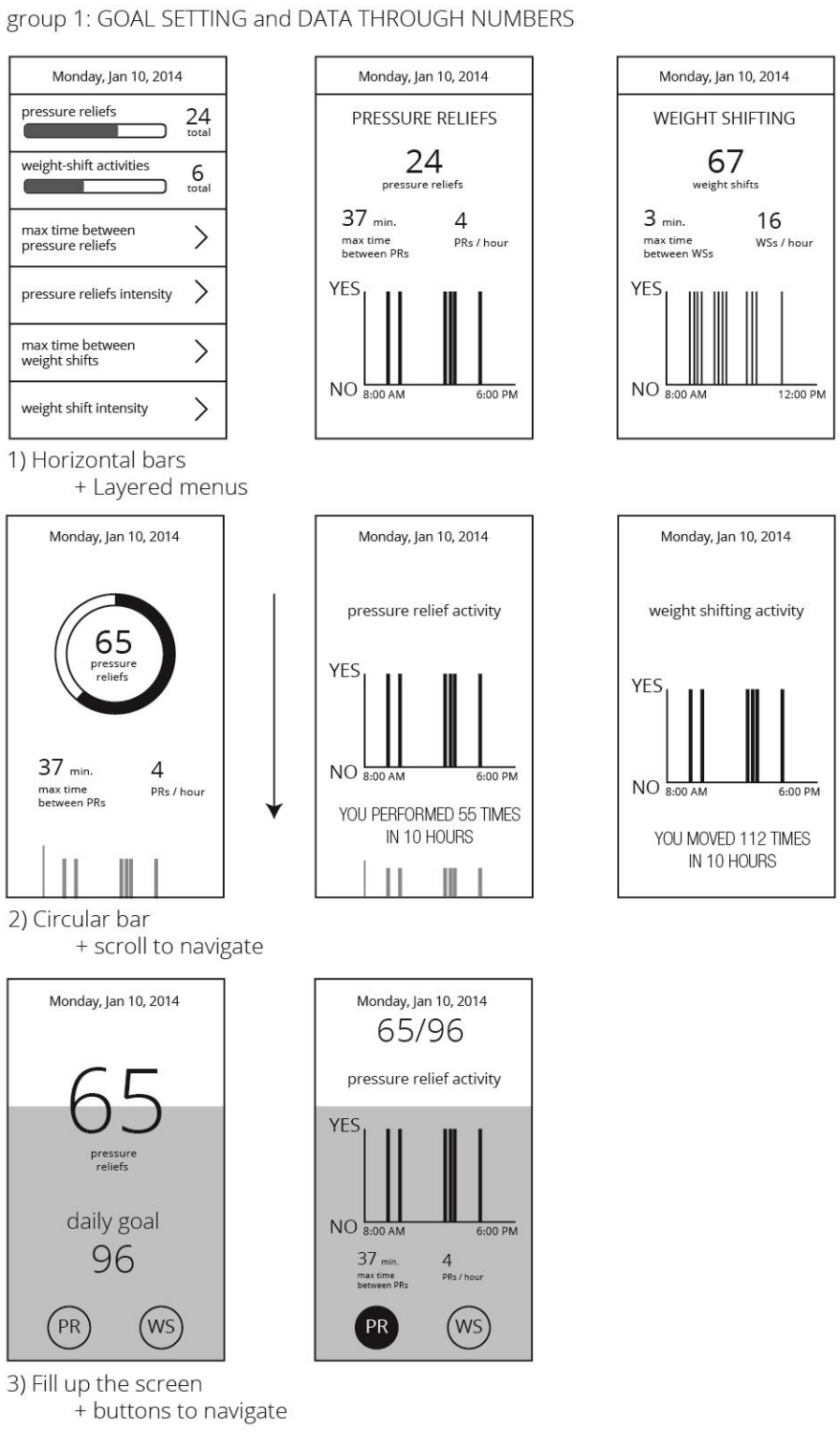

12) American baby

13) Moves

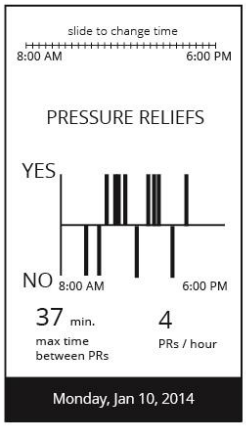
14) Waterlogged

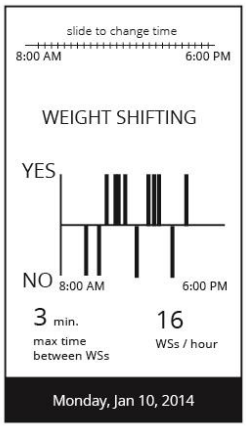
APPENDIX B

First design wireframes

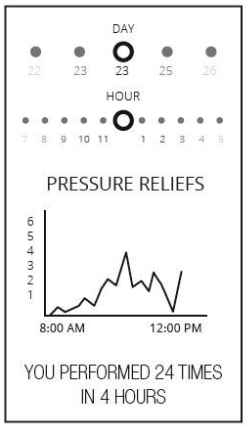


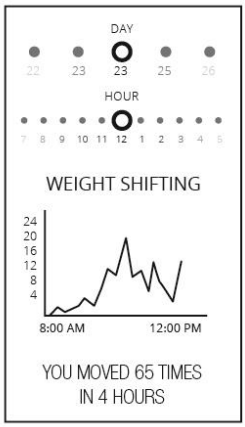
group 2: EXPLORING OTHER WAYS TO GRAPH

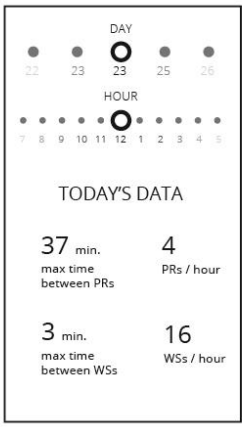




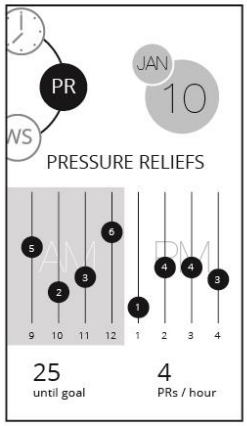
4) X-axis is neutral



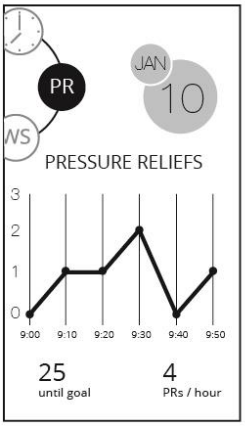




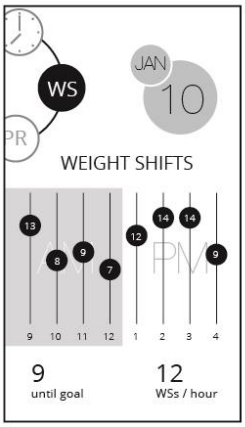
4) Line graph of mvmts per hour

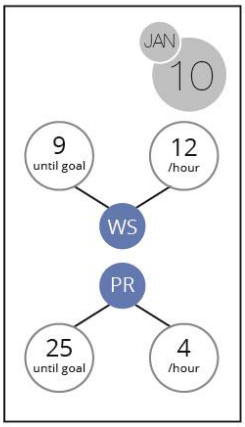


5) Combination graph

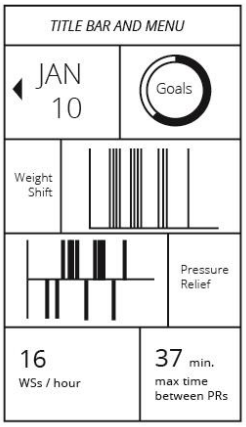


(zoomed in)

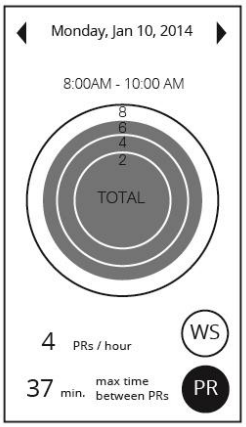


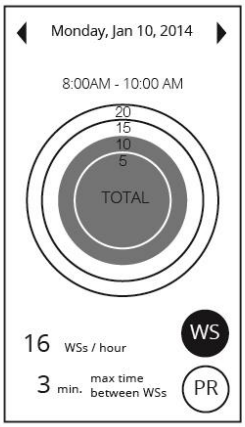


group 3: DISPLAYING INFORMATION

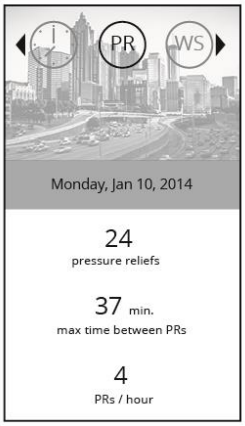


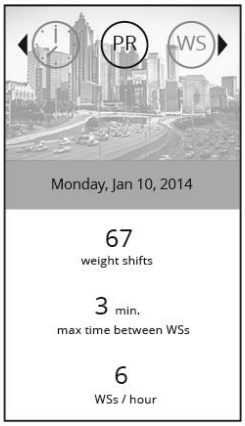
7) Staggered Grid





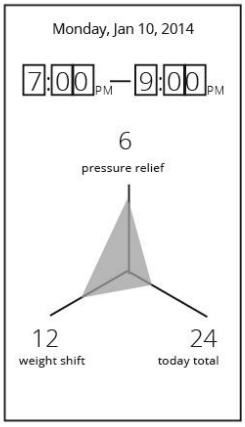
8) Concentric circles

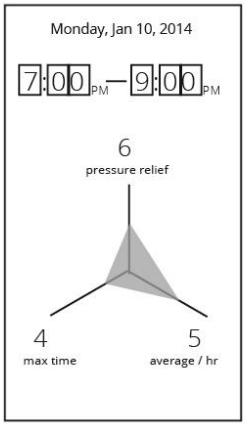


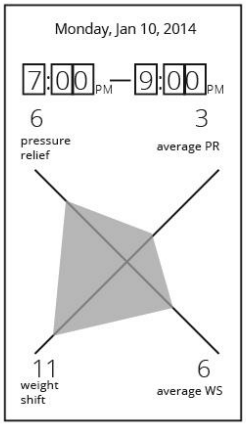


9) Just numbers

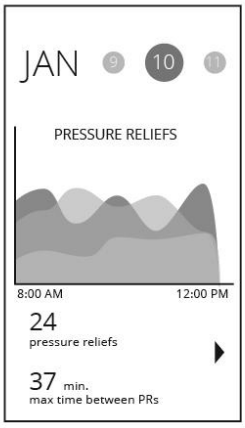
group 4: IDEATION

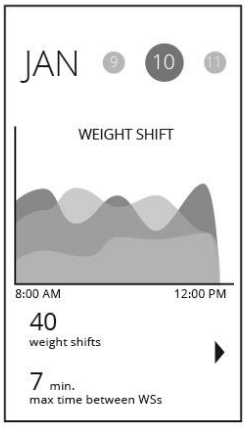




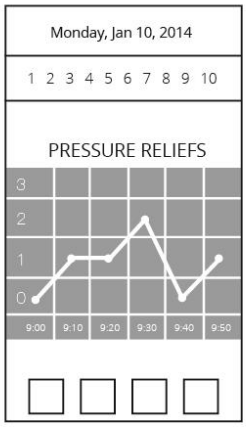


10) Polygon matrix





11) Layered graphs

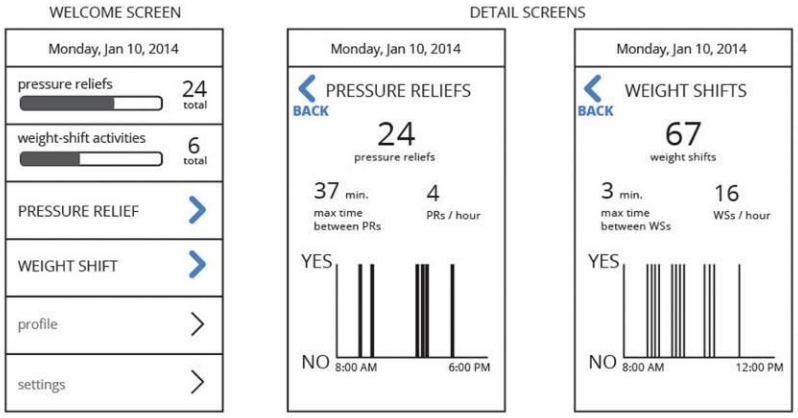


12) Graph

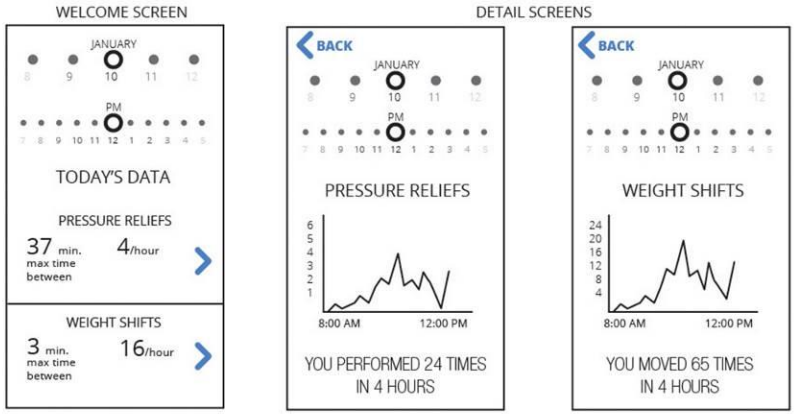
APPENDIX C

Five narrowed concepts

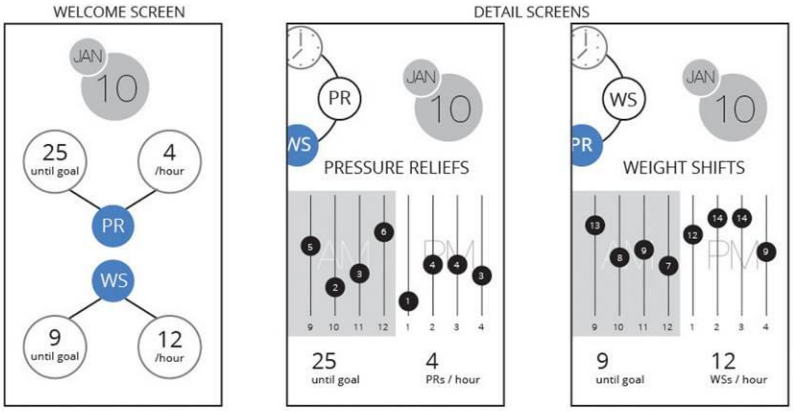
Design A



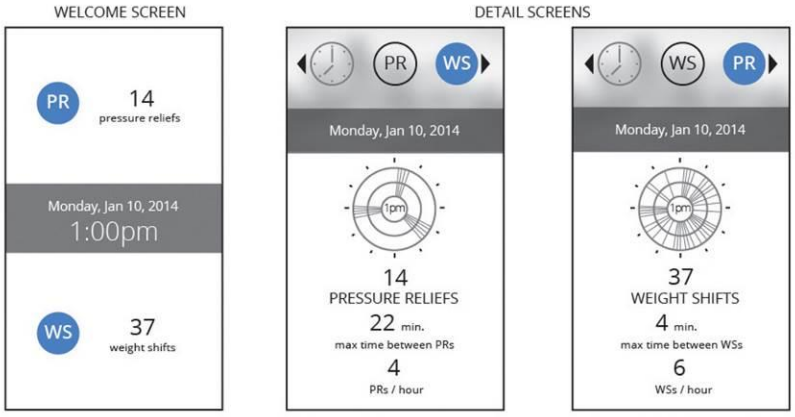
Design B



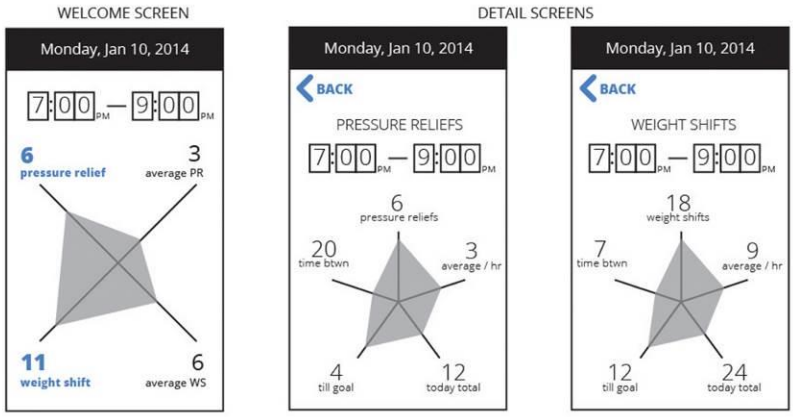
Design C



Design D



Design E



APPENDIX D

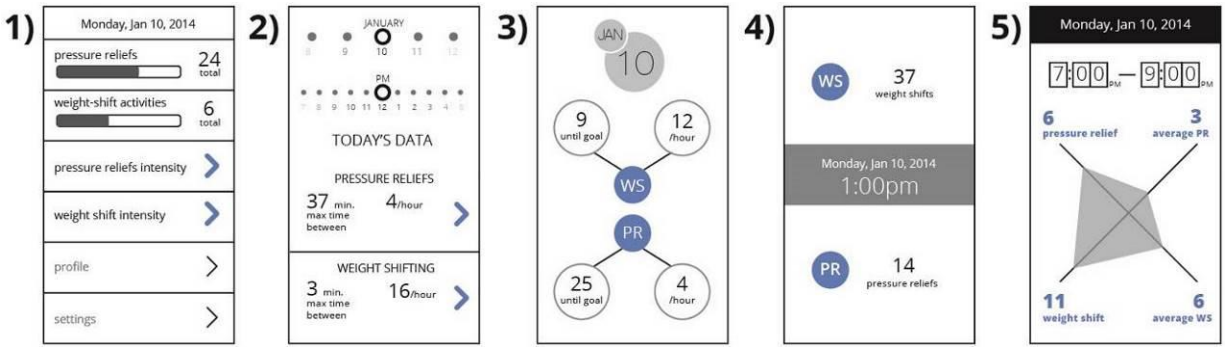
Survey for initial concept review

Thank you for volunteering to complete this survey. This survey is for a Georgia Tech Industrial Design Thesis project. Your answers will be used to design a smartphone application to inform wheelchair users about their weight shifting activities. The purpose of this survey is to evaluate FIVE initial designs and get feedback for potential features. The survey should take approximately 10 minutes to complete. All of your responses will remain anonymous. Participation is purely voluntary, and your input is greatly appreciated. If you have any questions, please contact Philip Cheng at pcheng35@gatech.edu.

Please take the time to read over the full consent form, which can be accessed here. If you complete this survey, it means you have read – or have had read to you – the information above as well as the full consent form and would like to be a volunteer in this research study. Press next when you are ready to begin.

We would like your opinion about the various ways in which weight shifting activities can be presented to wheelchair users. In the following concepts, **pressure reliefs (PRs)** are activities lasting >= 15 seconds whereas **weight-shift activities (WSs)** are movements lasting less time, and typically consist of fidgeting, reaching or leaning. A smartphone is any mobile phone that has an Android, iOS, or Windows Phone operating system with data or internet capabilities. The term "app" is short for application, any software installed onto the smartphone. In the following questions, the images are screens that would be presented in a smartphone app.

The following are five (5) example home screens that welcome the user once they open the app. Anything in blue indicates a button that the user can click to go into more detailed screens (which will be shown later).



1. Please rank each example home screen starting with the screen that, in your opinion, presents the clearest and most useful information, to the screen that has the least clear and least useful information. Again, the top choice is the screen that, in your opinion, presents the information in the clearest and most useful manner.

The following are more detailed screens that follow the home screen. Selecting the blue button or arrow on the home screen would transition to the respective PR or WS screen. The corresponding home screen is posted before each screen for reference.

For questions 2-11, please select how you feel about each statement, based on the clarity and usefulness of the presented screens.

Home screen

Detail screen

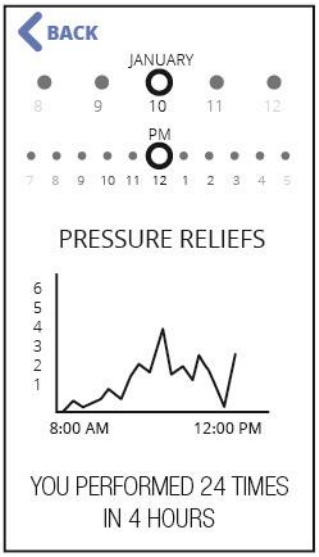
2. The information presentation is clear: 1 2 3 4

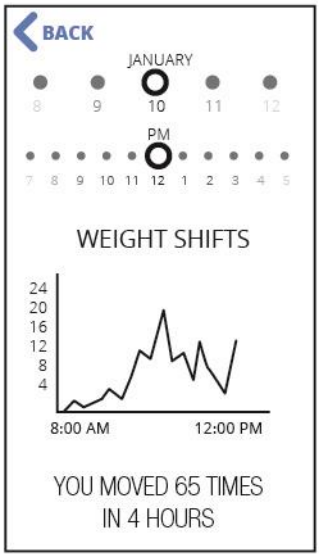
3. The information presentation is useful: 1 2 3 4

disagree agree

Home screen

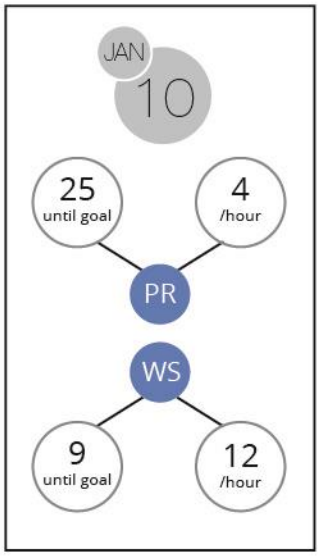
Detail screen



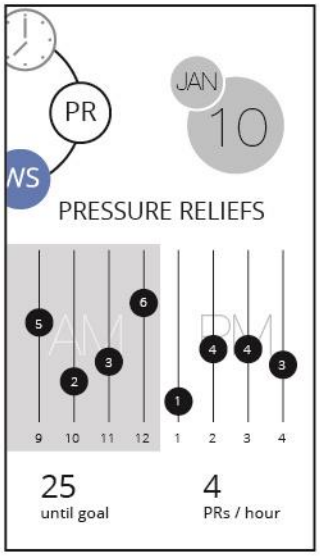


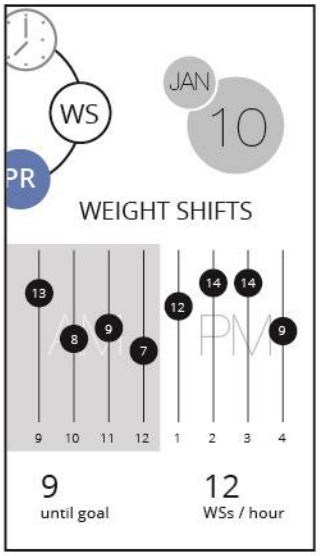
4. The information presentation is clear: 1 2 3 4
5. The information presentation is useful: 1 2 3 4
disagree agree

Home screen



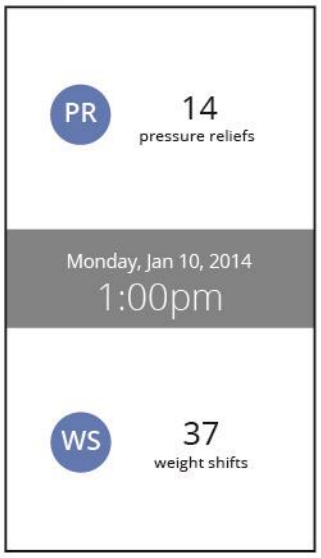
Detail screen



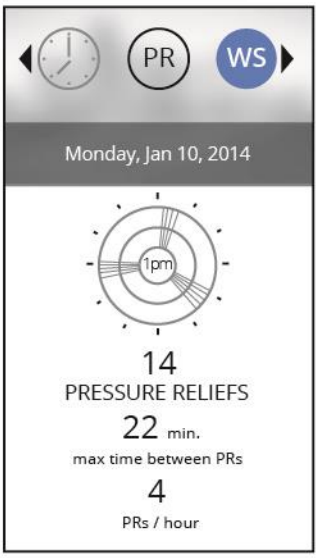


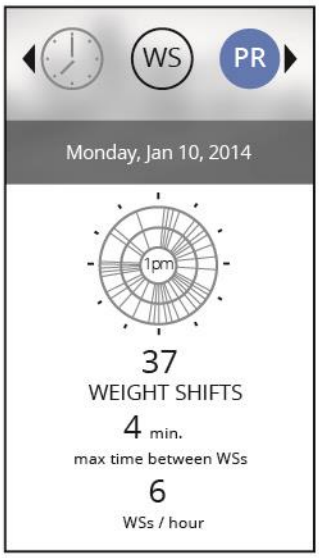
6. The information presentation is clear: 1 2 3 4
7. The information presentation is useful: 1 2 3 4
disagree agree

Home screen



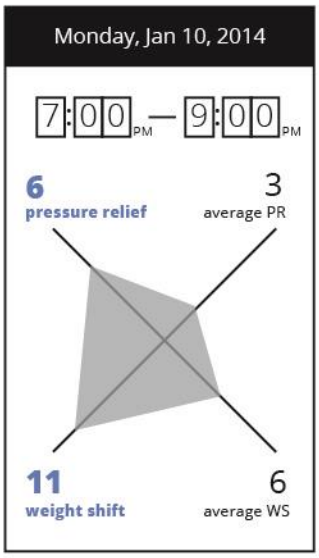
Detail screen



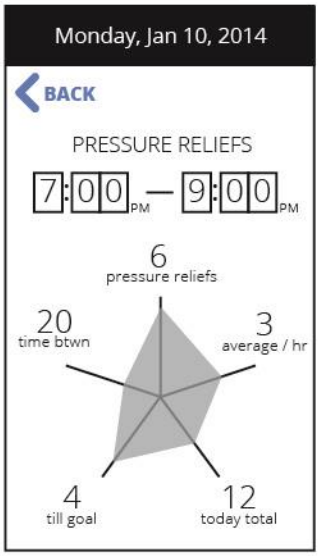


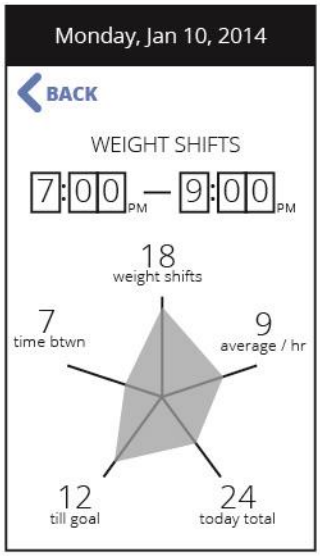
8. The information presentation is clear: 1 2 3 4
9. The information presentation is useful: 1 2 3 4
disagree agree

Home screen



Detail screen

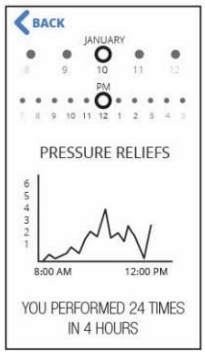


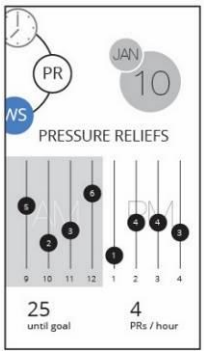


10. The information presentation is clear: 1 2 3 4
11. The information presentation is useful: 1 2 3 4
disagree agree

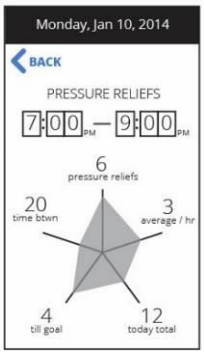
The following are five (5) example detail screens that were previously shown to you.

1) 

2) 

3) 

4) 

5) 

12. Please rank each example detail screen starting with the screen that, in your opinion, presents the clearest and most useful information, to the screen that has the least clear and least useful information. Again, the top choice is the screen that, in your opinion, presents the information in the clearest and most useful manner.

Drag the choices from the left hand box to right hand box. Release your cursor when you see a yellow box in right hand box. Choices can be rearranged after they have been placed on the right side by clicking and dragging them.

13. Do you use a smartphone on a daily basis?
    Yes __ No __
14. Do you use any health and/or fitness apps on your smartphone?
    Yes __ No __
15. How likely would you use the following features? Circle one answer for each feature.

a. Setting goal to move a certain amount throughout the day	Very likely	Likely	Unlikely	Very unlikely
b. Notification to prompt you to perform a pressure relief	Very likely	Likely	Unlikely	Very unlikely
c. Pressure relief exercise instructions and videos	Very likely	Likely	Unlikely	Very unlikely
d. Information on pressure ulcers	Very likely	Likely	Unlikely	Very unlikely
e. Weight shifting behavior history	Very likely	Likely	Unlikely	Very unlikely
f. List of local recreational activities (eg. sports, fitness, gardening) accessible to wheelchair users	Very likely	Likely	Unlikely	Very unlikely

16. Would you be willing to connect (“friend” them, see their information) to other wheelchair users through an app?
    Yes __ No __
17. If you could connect to other wheelchair users, would you message or talk to them?
    Yes __ No __

18. Would you be willing to share your weight shifting activities with others who also use the app?

    Yes __ No __

19. Do you think it would motivate you to perform more pressure relief exercises if you saw how others were behaving?

    Yes __ No __

20. What other features would you like to see in a weight shifting app?

THANK YOU FOR TAKING OUR SURVEY. YOUR RESPONSE IS VERY IMPORTANT TO US.

APPENDIX E

Recruitment scripts

Example script for online survey recruitment

Hi, my name is Philip Cheng. I am a Georgia Tech graduate student designing a new smartphone application to inform wheelchair users about their seating activity and to encourage them to perform pressure reliefs. I would appreciate it if you could help me in this project and complete the following survey. The purpose of this survey is to get your feedback on 5 different design ideas as well as additional features that could be added. Your answers will be used to create a product that will benefit wheelchair users in the future.

It will take approximately 5-10 minutes to complete. Your participation in this survey is completely voluntary, and you may stop at any time. Your identity is not gathered, and all of your responses will remain anonymous. Thank you for your time.
Link to survey: http://www.surveygizmo.com/s3/2040441/Philip-Cheng

Example script for in-person interview recruitment

VOLUNTEERS NEEDED: RESEARCH INTERVIEWS TO DEVELOP A NEW SMARTPHONE APP FOR WHEELCHAIR USERS

A Georgia Tech graduate research project is looking for volunteers to participate in a research study to give feedback on designs of a new smartphone app. The proposed app will help wheelchair users monitor their seating activity and encourage them to perform pressure reliefs to help reduce the likelihood of developing pressure ulcers. You will be asked to participate in a **30-minute** interview session consisting of filling out a survey and answering questions regarding the design.
To participate you must be:

1) **A full-time wheelchair user**
2) **Over the age of 18**
3) **Have used smartphone apps before**

In appreciation for your time, you will receive **$15**. Interview can be conducted at Shepherd Center or a location that is most convenient for you. To volunteer, please contact (914)-886-3171 or pcheng35@gatech.edu and leave a message with your name and number.

Contacts

Hilary Elliot, Charles James - *Disability Link*

Minna Hong, Mark Johnson, Mike Jones, John Morris, Pete Anziano, Matt Edens - *Shepherd Center*

Sharon Sonenblum, Maureen Linden - *Georgia Tech*

Paige Tidwell - *Georgia Rehabilitation Association*

Joel Reynolds, Gloria Weaver - *Emory ADSR office*

Paralyzed Veterans of America

Daphne Brooks, Liz Persaud - *Tools for life*

Rebecca S. Williams - *Southeast ADA Center*

Marisa Demaya, Sharon Finney - *Independent Living Research Utilization*

Andrea Van Hook - *Rehabilitation Engineering and Assistive Technology Society of North America*

Wheelchair Tennis Atlanta

APPENDIX F

Participant engagement plans

Initial concept review interview plan

1. Participant is introduced to the session and presented with the consent form. The following steps only occur if the participant consents to participate in the study. (~3 minutes)
2. Participant is given paper survey to complete. (~8 minutes)
3. Two usability task will be asked for them to complete for each of the five the designs using paper prototypes. The tasks are:
    a. From the home screen, go to the pressure relief , go back to the home screen, and go to the weight shift screen, and go back to the home screen
    b. Change the date that you would like to look at and check the history of your behavior.

    Researcher will show participant the paper prototype of the screen. When the participant makes the correct choice, the researcher will slide the participant the corresponding page. (~8 minutes)
4. Additional clarification questions will be asked for each design after the survey and usability tasks. This is done to get more insight into the design that would otherwise not be possible with the online survey. (~8 minutes)
    a. Question 2 example: Do you understand what the bar on the home screen is showing?
    b. Question 4 example: Can you read the circle graph? For example, how many weight shifts occur between 1:05pm and 1:15pm?
5. Session will wrap up and participant will be asked if they have any further comments. They will be asked if they would like to return for the second interview session. (~3 minutes)

Usability testing plan

1. Participant is introduced to the session and presented with the consent form. The following steps only occur if the participant consents to participate in the study. (~3 minutes)
2. Prototype number is randomly selected and participant is given the first prototype and asked to perform the listed tasks and timed. (~10 minutes)
3. Participant is given survey to evaluate their satisfaction and opinion of the first prototype. (~5 minutes)
4. The second prototype is given to the user and they will be asked to perform the same tasks and timed. (~10 minutes)
5. Participant is given the second survey to evaluate the second prototype. (~5 minutes)
6. Participant will be asked questions regarding their survey answers and comparing the two prototypes for further design feedback.

APPENDIX G

First survey results

Rspnse ID	Date Submitted	Device	Country	State/ Region	City	Question 1					Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11
						A	B	C	D	E	E		C		B		D		A	
19	2015-04-05 18:28:19	iPhone	U.S.A.	GA	Marietta	1					1	4	1	4	1	4	1	4	1	4
118	2015-05-05 22:40:35	Windows 7	India			2	1	4	3	5	3	4	4	3	3	4	3	4	3	4
116	2015-05-05 10:17:35	Macintosh OS	U.S.A.	TN	Lafayette	4	3	1	2	5	3	3	4	3	4	3	4	3	4	3
115	2015-05-05 08:45:54	Windows 7	U.S.A.	GA	Atlanta	3	5	2	1	4	1	1	2	1	2	2	3	1	2	1
114	2015-05-05 07:15:12	Windows 7	U.S.A.	PA	Windber						3	4	3	3	4	4	4	4	4	4
111	2015-05-04 17:32:25	Windows 8.1	U.S.A.	PA	Glenside	1	4	3	2	5	2	2	3	2	4	3	3	3	3	3
109	2015-05-04 01:24:29	Windows 7	India	36	Ghaziabad	1	5	3	2	4	3	4	4	3	3	3	4	4	3	4
106	2015-05-01 16:02:58	Windows 8.1	U.S.A.	NJ	West Orange	3	1	2	4	5	3	4	3	3	4	3	4	4	3	4
105	2015-04-30 16:27:32	Windows 8.1	U.S.A.	GA	Atlanta	2	1	3	4	5	2	2	2	3	4	4	3	3	2	2
104	2015-04-30 16:23:43	Windows 8.1	U.S.A.	GA	Atlanta	3	1	4	2	5	2	3	3	3	3	3	2	3	3	3
103	2015-04-30 16:21:57	Windows 8.1	U.S.A.	GA	Atlanta	3	5	2	1	4	2	3	2	2	2	4	4	4	3	4
102	2015-04-30 16:19:24	Windows 8.1	U.S.A.	GA	Atlanta	2	4	3	1	5	1	1	1	1	3	3	2	2	4	4
101	2015-04-30 16:12:47	Windows 8.1	U.S.A.	GA	Atlanta	3	1	4	2	5	4	3	4	4	2	2	2	2	4	4
99	2015-04-29 18:08:10	Windows 7	U.S.A.	SC	Laurens	1	3	4	2	5	1	1	1	1	2	2	3	3	4	4
96	2015-04-29 02:44:20	Windows 7	U.S.A.	UT	Salt Lake City	1	3	2	4	5	1	2	3	3	3	3	4	2	4	4
95	2015-04-29 02:33:02	Windows 8.1	U.S.A.	NY	Huntington St	2	3	1	4	5	2	3	2	3	4	4	3	4	3	4
93	2015-04-28 19:25:14	iPad	U.S.A.	VA	Norfolk	1	3	4	2	5	1	2	1	2	3	3	2	2	3	3
91	2015-04-28 19:02:04	Windows 7	U.S.A.	GA	Atlanta	3	5	2	1	4	3	3	3		3		3	1	2	3
89	2015-04-28 17:10:33	Windows 7	U.S.A.	CA	Modesto				1		1	1	1	2	2	1	2	2	2	2
87	2015-04-28 16:17:32	Windows 8.1	U.S.A.	GA	Smyrna	1	3	4	5	2	3	3	1	3	3	4	3	4	3	3
85	2015-04-28 13:11:59	Windows 7	U.S.A.	GA	Augusta	3	1	4	2	5	4	4	4	4	4	4	4	4	4	4
84	2015-04-28 12:04:01	Macintosh OS	U.S.A.	PA	Bala Cynwyd					1	3	3	4	4	2	2	1	2	2	1
83	2015-04-28 11:41:34	Windows 10	U.S.A.	NE	Bellevue	4	3	2	5	1	4	3	2	2	2	2	3	3	1	1
82	2015-04-28 11:18:07	Windows 7	U.S.A.	GA	Atlanta						1	1	1	1	1	1	1	1	1	1
81	2015-04-28 11:07:27	Windows 8.1	U.S.A.	IN	Indianapolis	1	5	2	3	4	2	3	1	3	2	2	2	3	3	3

Rspnse ID	Question 12					Q13	Q14	Q15a	Q15b	Q15c	Q15d	Q15e	Q15f	Q16	Q17	Q18	Q19
	A	B	C	D	E												
19						Yes	No	Very likely	Very likely	Very likely	Likely	Likely	Likely	Yes	Yes	Yes	Yes
118	5	1	3	2	4	Yes	Yes	Very likely	Likely	Very likely	Likely	Very likely	Likely	Yes	Yes	Yes	Yes
116	4	3	2	1	5	Yes	No	Very unlikely	Very unlikely	Very unlikely	Very unlikely	Very unlikely	Very unlikely	No	No	No	No
115	5	3	4	1	2	No	No	Very unlikely	Very unlikely	Very likely	Very unlikely	Very unlikely	Very unlikely	No	No	No	No
114	1	5	4	2	3	Yes	No	Likely	Likely	Likely	Likely	Very likely	Very likely	Yes	Yes	Yes	Yes
111	1	2	5	3	4	No	No	Very unlikely	Very unlikely	Very unlikely	Very unlikely	Very unlikely	Very unlikely	No	No	Yes	No
109	5	1	3	4	2	Yes	Yes	Very likely	Likely	Very likely	Likely	Very likely	Likely	Yes	Yes	Yes	Yes
106	5	2	4	1	3	Yes	Yes	Very likely	Likely	Very likely		Very likely	Very likely	Yes	Yes	Yes	No
105	4	1	3	2	5	Yes	Yes	Very likely	Very likely	Unlikely	Unlikely	Very likely	Very likely	Yes	Yes	Yes	Yes
104	2	3	1	4	5	Yes	No	Likely		Unlikely	Unlikely	Likely	Unlikely	Yes	Yes	No	No
103	5	2	4	1	3	Yes	No	Very likely	Very likely	Very likely	Very likely	Very likely	Very likely	Yes	Yes	Yes	Yes
102	1	3	2	4	5	Yes	Yes	Very likely	Likely	Likely	Very likely	Very likely	Very likely	Yes	Yes	Yes	Yes
101	3	5	2	4	1	Yes	No	Very likely	Very likely	Unlikely	Unlikely	Very likely	Likely	Yes	Yes	Yes	Yes
99	1	3	4	2	5	Yes	No	Unlikely	Likely	Likely	Likely	Likely	Very likely	Yes	Yes	Yes	Yes
96	1	5	2	3	4	Yes	Yes	Unlikely	Very likely	Very likely	Likely	Very likely	Very likely	Yes		Yes	No
95	3	2	1	4	5	No	No	Likely	Unlikely	Very unlikely	Likely	Likely	Likely	Yes	Yes	Yes	Yes
93	3	1	4	2	5	Yes	Yes	Very likely	Very likely	Very likely	Likely	Likely	Likely	Yes	Yes	No	No
91	5	2	4	1	3	No	No	Unlikely	Likely	Very unlikely	Very unlikely	Unlikely	Likely	No	No	No	Yes
89				1		Yes	No	Unlikely	Likely	Very unlikely	Very unlikely	Unlikely	Very likely	No	No	No	No
87	5	3	2	1	4	No	No	Likely	Likely	Likely	Likely	Likely	Very likely	Yes	Yes	Yes	Yes
85	2	1	3	4	5	Yes	No	Likely	Very likely	Unlikely	Likely	Very likely	Very likely	Yes	Yes	Yes	No
84	5	3	2	4	1	No	No	Very unlikely	Very unlikely	Likely	Very unlikely	Unlikely	Very likely	Yes	No	No	No
83	5	3	4	2	1	Yes	No	Likely	Likely	Likely	Likely	Likely	Unlikely	Yes	Yes	Yes	Yes
82						Yes	No	Very unlikely	Very unlikely	Very unlikely	Very unlikely	Very unlikely	Very unlikely	No	No	No	No
81	1	3	2	4	5	Yes	No	Very likely	Very likely	Likely	Likely	Unlikely	Unlikely	No	No	Yes	No

Rspnse ID	Q20
19	A sound that reminds me to do weight shifts
118	it is ti have smartphone feature linked with wheelchair
116	
115	No answer available at this time..
114	NONE
111	I refuse to be tethered to a screen. I am not a person who looks at his phone all the time. So, really, I am not a good person to have answer your questionnaire.
109	videos showing the situations of sitting
106	
105	what exercises are good? questions asking how I feel today and if I feel my skin breaking down. nutrition information for good foods to eat (zinc, multivitamins with minerals, high-protein)
104	voice recognition
103	modification's for other disabilities (ie blind and hearing impaired) if it doesn't already adapt or integrate with existing systems on the market
102	alarms
101	continuous alarm until shift, if can tie into pressure map - signal when achieving full relief
99	Wheelchair status.
96	I would think a report of where we are keeping our weight and possibly prompts to shift from that particular area in addition to the normal weight shifts. If we are right front leaners for a majority of or at least a major percentage of the time we need to know this so that we can change our position. I know what I mean and hope that you understand what I am talking about. I get sore elbows and sore on my right side most from leaning. I hope this helps.
95	areas that highlight in red where there are 'hot spots' aka areas very vulnerable to skin breakdown or starting to do so
93	Visual clarity for aging and low vision users. Most of these screens are too crowded even for a well-educated user.
91	unsure.
89	Mainly information communicated to therapists so they can check if seating is good or not.
87	animation and music!
85	None
84	
83	
82	yall call me, i am a user and can show you what to focus on.
81	affordable!

Rspnse ID	Date Submitted	Device	Country	State/ Region	City	Question 1					Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11
						A	B	C	D	E	E		C		B		D		A	
80	2015-04-28 10:41:33	Android 4.0.4	U.S.A.			4	2	3	1	5	2	2	2	2	2	2				
77	2015-04-28 10:09:28	Windows 7	U.S.A.	GA	Lawrenceville	1	2	4	3	5	1	2	2	2	4	4	3	4	4	4
69	2015-04-24 10:37:53	Windows 8.1	U.S.A.	GA	Alpharetta	1	2	5	4	3	4	4	2	4	4	4	3	4	3	4
62	2015-04-21 20:54:54	Windows 7	U.S.A.	GA	Fitzgerald	1	3	2	5	4	4	4	3	4	3	4	4	4	3	3
59	2015-04-21 19:21:00	Windows 8.1	U.S.A.	FL	Palm Harbor	3	1	5	2	4	3	4	3	3	4	4	3	3	4	4
58	2015-04-21 19:14:08	Windows 8.1	U.S.A.	GA	Statham	2	1	3	4	5	4	4	4	4	4	4	4	4	4	4
57	2015-04-21 18:38:45	Windows 7	U.S.A.	GA	Norcross	1	2	5	4	3	2	3	2	2	3	3	3	3	4	4
56	2015-04-21 18:22:46	iPhone	U.S.A.	NY	Buffalo	1	2	4	3	5	2	4			4	3	4	3	4	3
54	2015-04-21 17:47:00	Macintosh OS	U.S.A.	GA	Atlanta	4	2	1	3	5	1	2	3	3	3	3	2	3	3	3
53	2015-04-21 17:45:45	Macintosh OS	U.S.A.	GA	Atlanta	3	5	4	2	1	2	3	2	3	3	3	4	2	2	2
52	2015-04-21 17:22:20	iPad	U.S.A.	GA	Cumming	5	2	4	3	1	3	3	3	3	3	3	2	2	2	3
51	2015-04-21 16:54:44	Windows 7	U.S.A.	GA	Atlanta	2	4	3	1	5	2	3	2	3	3	3	3	3	2	3
43	2015-04-14 12:15:43	Android 4.0.2	U.S.A.	GA	Lithonia	5	2	1	4	3			3	2	2	3	2	3	3	3
40	2015-04-13 18:12:28	Windows 8.1	U.S.A.	GA	Moultrie	1	2	4	3	5	2	2	3	3	2	2	3	3	3	3
39	2015-04-13 17:00:07	Windows 7	U.S.A.	GA	Atlanta	1	2	3	5	4	2	3	2	2	3	2	3	3	3	4
38	2015-04-13 16:32:11	iPhone	U.S.A.	GA	Lawrenceville						2	4	4	2	1	4	4	3	4	
37	2015-04-11 21:30:10	Macintosh OS	U.S.A.	GA	Atlanta	2	3	4	1	5	2	2	2	2	3	3	4	4	3	3
35	2015-04-09 14:36:35	iPhone	U.S.A.	GA	Fayetteville	1	2				2	2	4	4	3	4	1	2	2	4
32	2015-04-08 11:27:50	Windows 7	U.S.A.			3	5	2	1	4	3	3	3	3	3	3	3	3	3	3
30	2015-04-08 10:52:01	Windows 7	U.S.A.	GA	Alpharetta	1					1	1	2	1	3	3	3	2	3	2
29	2015-04-08 10:09:38	Windows 7	U.S.A.	NC	Charlotte	2	1	3	5	4	1	2	1	2	1	2	1	2	1	1
24	2015-04-07 15:23:54	Windows 7	U.S.A.	GA	Powder Sprin	3	2	4	1	5	2	3	2	3	2	3	3	3	3	3
23	2015-04-07 15:06:21	Macintosh OS	U.S.A.	GA	Atlanta	2	4	3	1	5	1	3	1	3	2	3	4	4	3	4
22	2015-04-07 15:31:18	Windows XP	Uruguay	10	Montevideo	5	1	4	2	3	1	3	3	2	4	2	3	3	2	3
20	2015-04-07 15:00:52	Windows XP	U.S.A.	GA	Atlanta	2	1	5	3	4	2	3	2	3	4	4	2	3	3	3

Rspnse ID	Question 12					Q13	Q14	Q15a	Q15b	Q15c	Q15d	Q15e	Q15f	Q16	Q17	Q18	Q19
	A	B	C	D	E												
80	2	1	3	4	5	Yes		Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	Very likely	Yes	Yes	No	No
77	1	2	3	4	5	Yes	No	Likely	Very likely	Very likely	Unlikely	Unlikely	Very likely	Yes	Yes	Yes	Yes
69	5	1	2	4	3	Yes	No	Likely	Likely	Unlikely	Unlikely	Very likely	Likely	Yes	Yes	Yes	Yes
62	5	4	1	3	2	Yes	No	Likely	Very likely	Likely	Unlikely	Likely	Very likely	Yes	Yes	Yes	Yes
59	4	2	3	1	5	Yes	Yes	Very likely	Likely	Unlikely	Unlikely	Very likely	Likely	Yes	Yes	Yes	Yes
58	1	2	4	3	5	Yes	No	Likely	Likely	Likely	Very likely	Very likely	Very likely	Yes	Yes	Yes	Yes
57	3	1	2	4	5	Yes	Yes	Unlikely	Likely	Likely	Likely	Likely	Very likely	No	No	No	No
56	1	3	2	4	5	Yes	Yes	Likely	Unlikely	Unlikely	Unlikely	Likely	Likely	Yes	Yes	Yes	Yes
54	3	1	2	4	5	Yes	No	Unlikely	Very unlikely	Very unlikely	Very unlikely	Very unlikely	Very unlikely	No	No	No	No
53	2	1	5	4	3	Yes	No	Likely	Unlikely	Very unlikely	Unlikely	Likely	Very unlikely	No	No	Yes	Yes
52	1	4	5	3	2	No	No	Likely	Likely	Likely	Likely	Likely	Likely	No	No	No	Yes
51	2	5	4	3	1	Yes	Yes	Likely	Very unlikely	Very unlikely	Unlikely	Very likely	Very likely	No	No	No	No
43						No	No	Unlikely	Likely	Likely	Likely	Unlikely	Unlikely	Yes	No	No	No
40	3	4	5	1	2	Yes	No	Likely	Likely	Likely	Unlikely	Likely	Likely	No	No	Yes	Yes
39	1	4	2	3	5	Yes	Yes	Very likely	Likely	Unlikely	Likely	Likely	Very likely	Yes	Yes	No	No
38																	
37	3	2	4	1	5	Yes	No	Unlikely	Likely	Unlikely	Unlikely	Likely	Very likely	Yes	Yes	No	No
35	3	2	1	4		Yes	No	Likely	Likely	Likely	Likely	Likely	Likely	No	Yes	No	No
32	4	3	2	1	5	Yes	No	Likely	Likely	Likely	Unlikely	Likely	Likely	Yes	Yes	No	No
30	2	1	5	3	4	No	No	Very unlikely	Likely	Very unlikely	Unlikely	Very unlikely	Likely	No	No	No	No
29	3	5	4	2	1	Yes	No	Likely	Very likely	Very unlikely	Very unlikely	Likely	Very unlikely	No	No	Yes	No
24	4	1	3	2	5	Yes	No	Likely	Likely	Likely	Likely	Likely	Likely	Yes	Yes	Yes	Yes
23	2	3	4	1	5	Yes	No	Likely	Likely	Likely	Unlikely	Likely		No	No	Yes	No
22	3	1	2	4	5	Yes	No	Very likely	Unlikely	Likely	Very unlikely	Very likely	Likely	Yes	No	No	No
20	2	1	5	3	4	Yes	Yes	Likely	Very likely	Unlikely	Unlikely	Very likely	Likely	No	No	No	No

Rspnse ID	Q20
80	
77	This would be great on a smart watch as well.
69	I like the ability to see how many, when, intensity, maximum time in between. The goal information is not that valuable to me. I know what
62	Data comparing those who weight shift vs. those who don't. Skin health tips.
59	
58	
57	
56	
54	
53	
52	
51	
43	
40	
39	I would like a "fart" sound from my iPhone when I meet my hourly goal, with a text message that encourages me to meet my next goal. Thanks, guys. This looks pretty cool! Good Luck!
38	
37	
35	
32	
30	
29	All I want is an app that reminds me to perform a PR every 30 mins and also acts as a timer for duration of the PR (30 mins/60 secs). I don't understand at all how you intend for this app to work. Do I have to enter data every time I perform a PR or WS? If so it seems like I'll spend all day on my smart phone.
24	
23	iOS app integration with Apple Watch for reminders
22	
20	

Pivot tables

Regular smartphone user vs choosing the following home screen as #1	No	Yes	Grand Total
A	2	12	14
B		11	11
C	2	2	4
D	2	8	10
E	1	2	3
(blank)			
Grand Total	**7**	**35**	**42**

Uses health/fitness apps vs choosing the following home screen as #1		No	Yes	Grand Total
A		8	6	14
B		6	5	11
C		4		4
D	1	7	2	10
E		3		3
(blank)				
Grand Total	**1**	**28**	**13**	**42**

Regular smartphone user vs choosing the following detail screen as #1	No	Yes	Grand Total
A	2	9	11
B	1	13	14
C	1	3	4
D	3	8	11
E	1	4	5
(blank)			
Grand Total	**8**	**37**	**45**

Uses health/fitness apps vs choosing the following detail screen as #1		No	Yes	Grand Total
A		7	4	11
B	1	7	6	14
C		4		4
D		9	2	11
E		4	1	5
(blank)				
Grand Total	**1**	**31**	**13**	**45**

Willingness to connect to other wheelchair users (Q16) vs message/talk them (Q17)	unanswered	No	Yes	Grand Total
	1		1	2
No		17	3	20
Yes		1	27	28
Grand Total	**1**	**18**	**31**	**50**

Regular smartphone user (Q13) vs likelihood to use notification prompt (Q15b)	unanswered	No	Yes	Grand Total
	1		1	2
Very likely			12	12
Likely		5	19	24
Unlikely		1	4	5
Very unlikely		3	4	7
Grand Total	**1**	**9**	**40**	**50**

Being motivated by seeing other's people's data (Q 19) vs likelihood to use goal setting fuction (Q 15a)	unanswered	No	Yes	Grand Total
	1			1
Very likely		5	8	13
Likely		8	13	21
Unlikely		7	2	9
Very unlikely		6		6
Grand Total	**1**	**26**	**23**	**50**

Total results = highest result

Question 1 -ranking

	SCREEN				
	A	B	C	D	E
1st position	14	11	4	10	3
2nd position	10	11	9	11	1
3rd position	11	9	10	8	4
4th position	4	4	15	8	11
5th position	3	7	4	5	23

	"The information presented is clear"		**"The information presented is useful"**	
	answers >= 3	answers <= 2	answers >= 3	answers <= 2
Screen A	35	14	40	9
Screen B	33	17	35	14
Screen C	23	26	30	18
Screen D	34	15	35	14
Screen E	17	31	31	18

Question 12 - ranking

	SCREEN				
	A	B	C	D	E
1st position	11	14	4	11	5
2nd position	8	10	14	8	5
3rd position	10	12	8	9	6
4th position	5	4	13	17	6
5th position	11	5	6	0	22

= highest result

Results measured against those who do use smartphones daily

Question 1 -ranking

	SCREEN				
	A	B	C	D	E
1st position	12	11	2	8	2
2nd position	9	9	7	10	0
3rd position	9	7	9	7	3
4th position	4	3	13	6	9
5th position	1	5	4	4	21

	"The information presented is clear"		**"The information presented is useful"**	
	answers >= 3	answers <= 2	answers >= 3	answers <= 2
Screen A	29	10	33	6
Screen B	27	13	29	11
Screen C	17	22	25	14
Screen D	27	12	30	9
Screen E	13	27	26	14

Question 12 - ranking

	SCREEN				
	A	B	C	D	E
1st position	9	13	3	8	4
2nd position	7	7	12	8	3
3rd position	9	9	8	6	5
4th position	5	3	11	15	3
5th position	7	5	3	0	21

= highest result

Results measured against those who do not use fitness apps on their smartphone (n=35)

Question 1 -ranking

	SCREEN				
	A	B	C	D	E
1	8	6	4	8	3
2	5	7	7	8	1
3	9	7	4	5	3
4	3	2	12	4	7
5	3	6	1	4	14

	"The information presented is clear"		**"The information presented is useful"**	
	answers >= 3	answers <= 2	answers >= 3	answers <= 2
Screen A	24	12	28	8
Screen B	20	17	23	13
Screen C	18	19	22	14
Screen D	24	12	25	11
Screen E	13	22	22	14

Question 12 - ranking

	SCREEN				
	A	B	C	D	E
1	7	7	4	10	4
2	5	8	9	5	4
3	8	10	3	5	5
4	3	3	10	12	3
5	8	3	5	0	14

Results measured against those who use fitness apps on their smartphones (n=13)

Question 1 -ranking

	SCREEN				
	A	B	C	D	E
1	6	5	0	2	0
2	5	3	2	3	0
3	2	2	5	3	1
4	0	2	3	4	4
5	0	1	3	1	8

	"The information presented is clear"		**"The information presented is useful"**	
	answers >= 3	answers <= 2	answers >= 3	answers <= 2
Screen A	11	2	12	1
Screen B	13	0	12	1
Screen C	5	7	8	4
Screen D	10	3	10	3
Screen E	4	9	9	4

Question 12 - ranking

	SCREEN				
	A	B	C	D	E
1	4	6	0	2	1
2	2	2	5	3	1
3	2	2	4	4	1
4	2	1	3	4	3
5	3	2	1	0	7

Weighted Tables

Total weighted score of home screens in Question 1

Rank	*Weight score*	*Screen*
1	169	A
2	145	B
3	144	D
4	120	C
5	81	E
Total responses	47	

Total weighted score of detail screens in Question 12

Rank	*Weight score*	*Screen*
1	159	B
2	153	D
3	138	A
4	132	C
5	97	E
Total responses	46	

Weighted score of home screens in Question 1 with regular smartphone users

Rank	*Weight score*	*Screen*
1	132	A
2	123	B
3	117	D
4	95	C
5	58	E
Total responses	35	

Weighted score of detail screens in Question 12 with regular smartphone users

Rank	*Weight score*	*Screen*
1	131	B
2	120	D
3	117	A
4	112	C
5	74	E
Total responses	37	

Weighted score of home screens in Question 1 of fitness app users

Rank	*Weight score*	*Screen*
1	56	A
2	48	B
3	40	D
4	32	C
5	19	E
Total responses	13	

Weighted score of detail screens in Question 12 fitness app users

Rank	*Weight score*	*Screen*
1	48	B
2	42	D
3	41	A
4	39	C
5	25	E
Total responses	13	

Weighted score of home screens in Question 1 of non-fitness app users

Rank	*Weight score*	*Screen*
1	99	D
2	96	A
3	89	B
4	85	C
5	56	E
Total responses	35	

Weighted score of detail screens in Question 12 non-fitness app users

Rank	*Weight score*	*Screen*
1	109	D
2	106	B
3	93	A
4	90	C
5	71	E
Total responses	35	

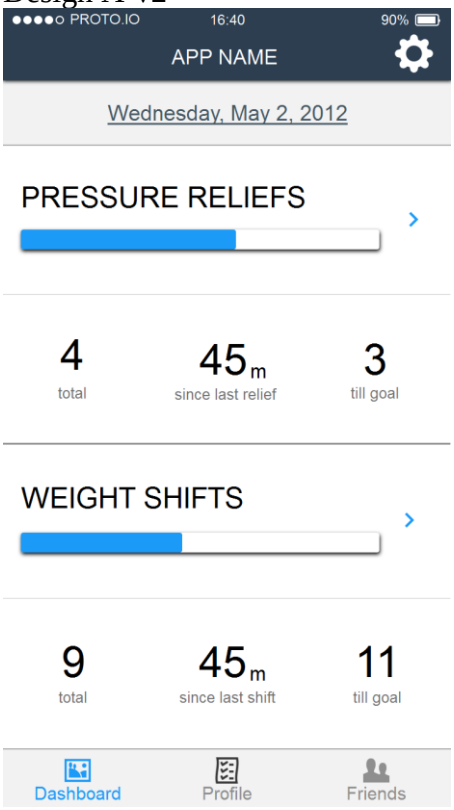
Number of people and distribution of responses for Question 15: How likely would you use the following features?

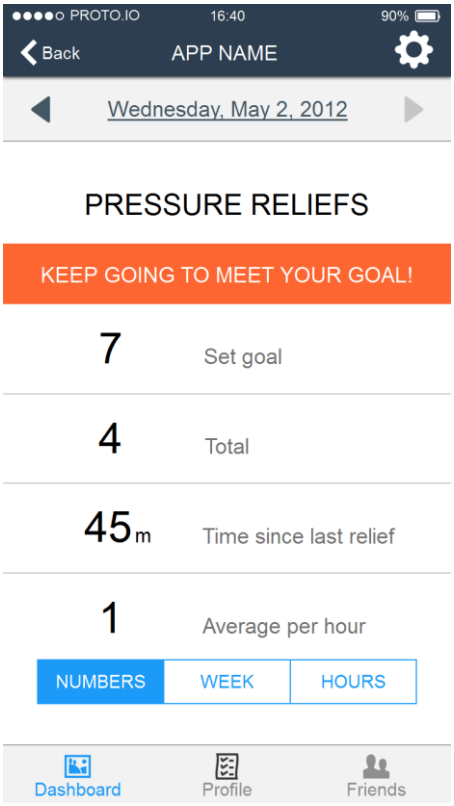
Task	**Very unlikely**	**Unlikely**	**Likely**	**Very likely**	**Total responses**
Setting goal to move a certain amount	6 12.2%	9 18.4%	21 42.9%	13 26.5%	49
Notification to prompt you to perform a pressure relief	7 14.6%	5 10.4%	24 50.0%	12 25.0%	48
Pressure relief exercise instructions and videos	11 22.4%	11 22.4%	18 36.7%	9 18.4%	49
Information on pressure ulcers	10 20.8%	17 35.4%	18 37.5%	3 6.3%	48
Weight shifting behavior history	6 12.2%	7 14.3%	20 40.8%	16 32.7%	49
List of local recreational activities accessible to wheelchair users	7 14.6%	4 8.3%	18 37.5%	19 39.6%	48

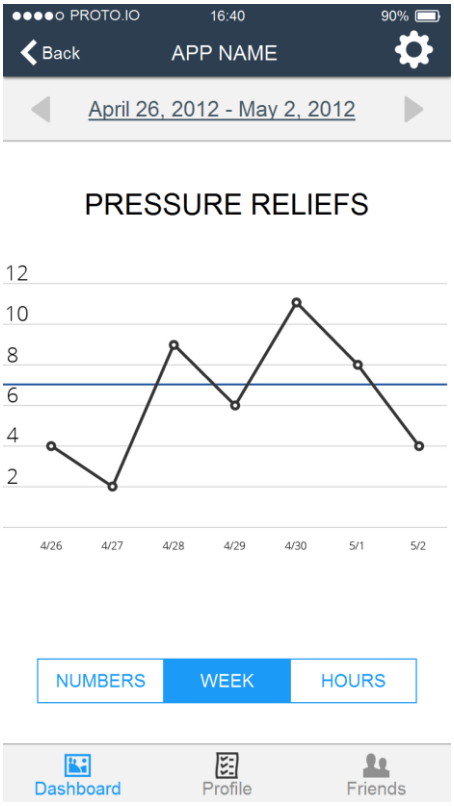
APPENDIX H

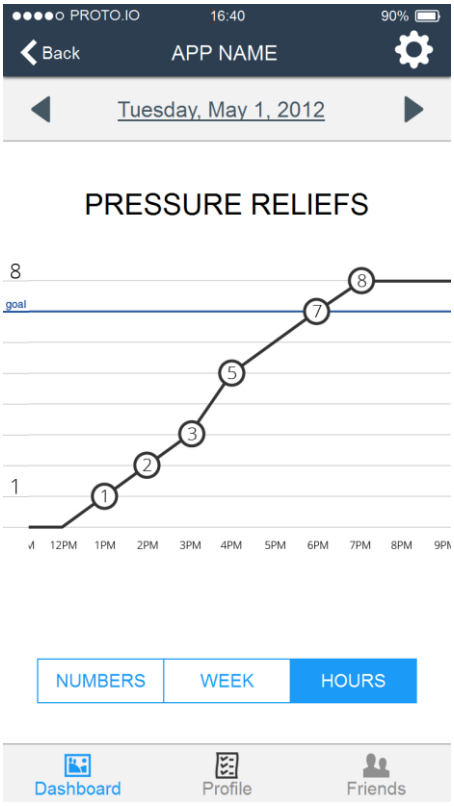
Designs for usability testing

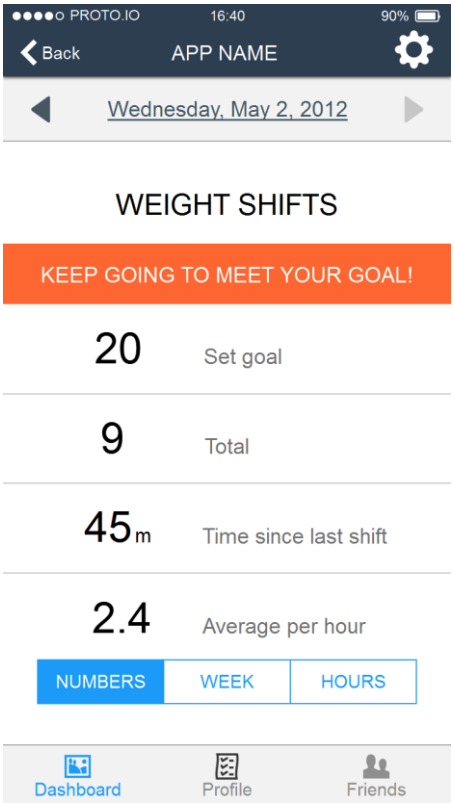
Design A-v2

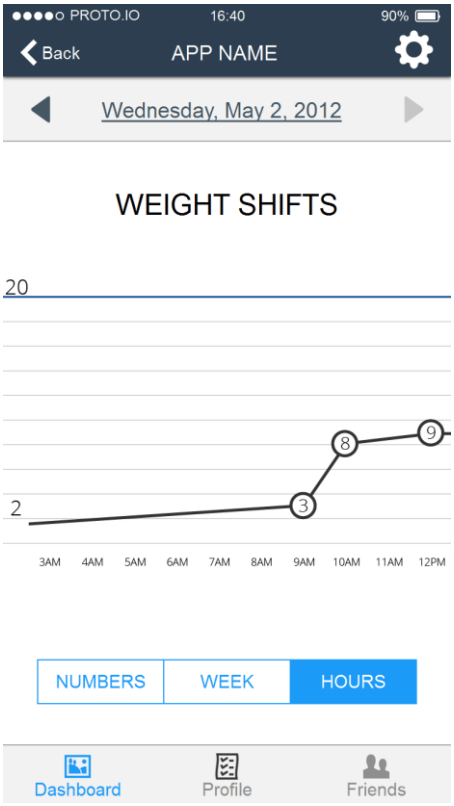


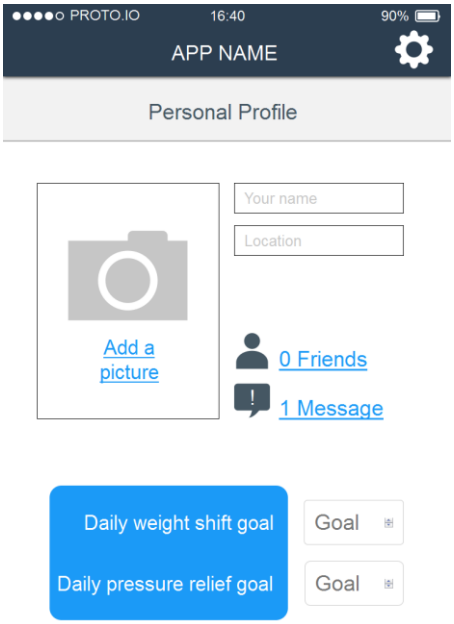


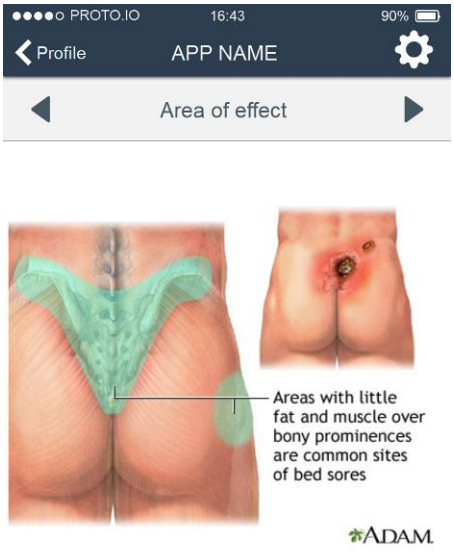

PROTO.IO 16:40 90%
Back
APP NAME
April 26, 2012 - May 2, 2012
PRESSURE RELIEFS
12
10
8
6
4
2
4/26 4/27 4/28 4/29 4/30 5/1 5/2
NUMBERS WEEK HOURS
Dashboard Profile Friends

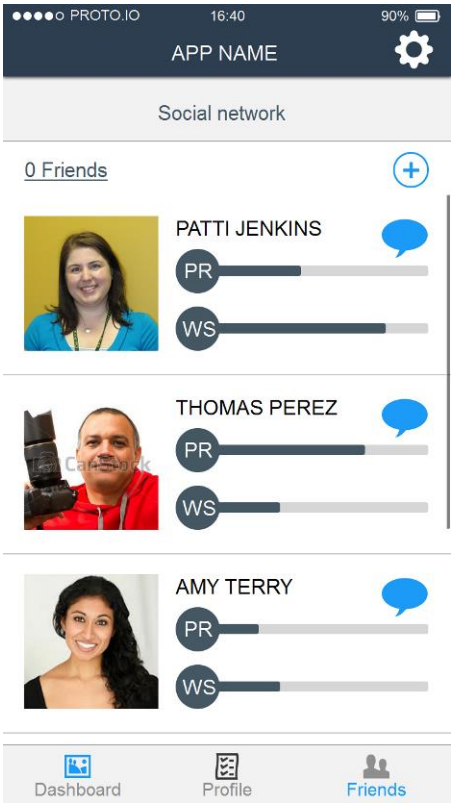

PROTO.IO 16:40 90%
Back
APP NAME
Tuesday, May 1, 2012
PRESSURE RELIEFS
8
goal
1
12PM 1PM 2PM 3PM 4PM 5PM 6PM 7PM 8PM
NUMBERS WEEK HOURS
Dashboard Profile Friends

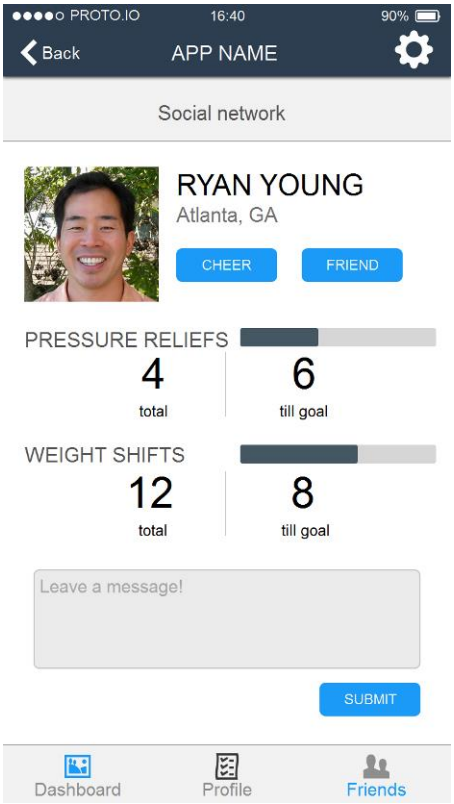

PROTO.IO 16:40 90%
Back
APP NAME
Wednesday, May 2, 2012
WEIGHT SHIFTS
KEEP GOING TO MEET YOUR GOAL!
20 Set goal
9 Total
45m Time since last shift
2.4 Average per hour
NUMBERS WEEK HOURS
Dashboard Profile Friends

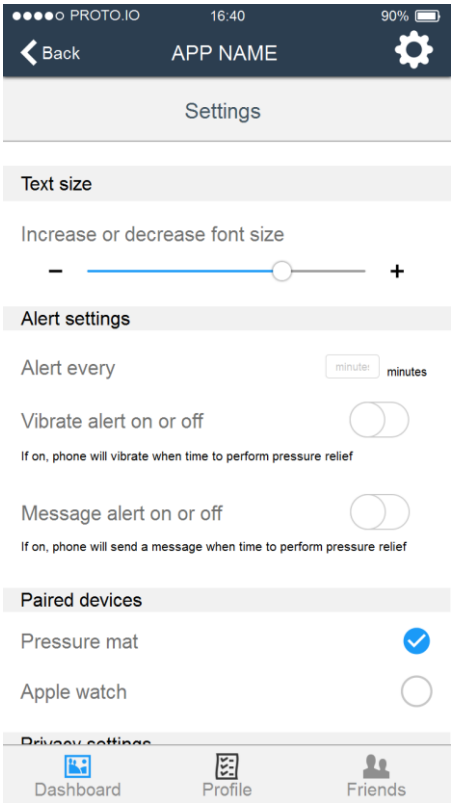

PROTO.IO 16:40 90%
Back
APP NAME
Wednesday, May 2, 2012
WEIGHT SHIFTS
20
2
3AM 4AM 5AM 6AM 7AM 8AM 9AM 10AM 11AM 12PM
NUMBERS WEEK HOURS
Dashboard Profile Friends


PROTO.IO 16:40 90%
APP NAME
Personal Profile
Your name
Location
Add a picture
0 Friends
1 Message
Daily weight shift goal
Goal
Daily pressure relief goal
Goal
Training information
Dashboard
Profile
Friends

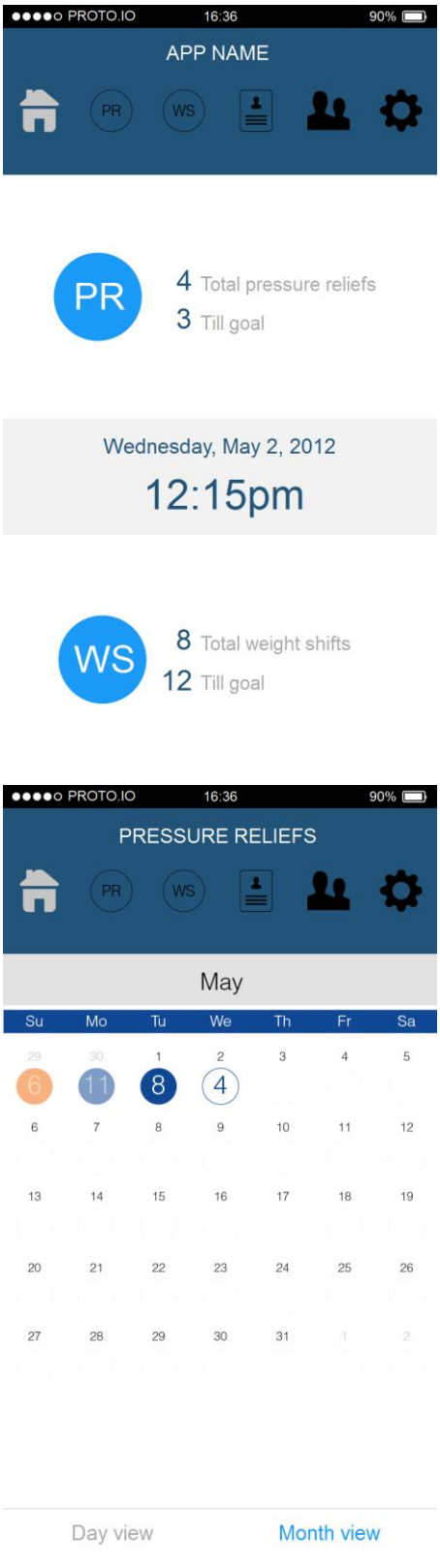

PROTO.IO 16:43 90%
Profile
APP NAME
Area of effect
Areas with little fat and muscle over bony prominences are common sites of bed sores
ADAM.
Dashboard
Profile
Friends

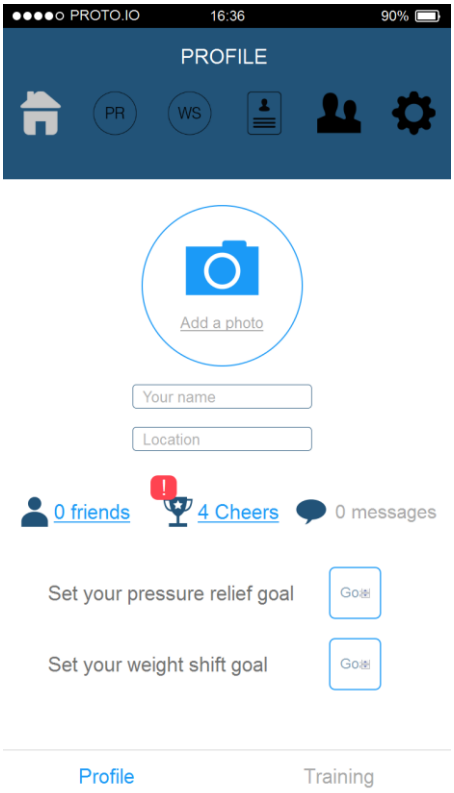

PROTO.IO 16:40 90%
APP NAME
Social network
0 Friends
PATTI JENKINS
PR
WS
THOMAS PEREZ
PR
WS
AMY TERRY
PR
WS
Dashboard
Profile
Friends

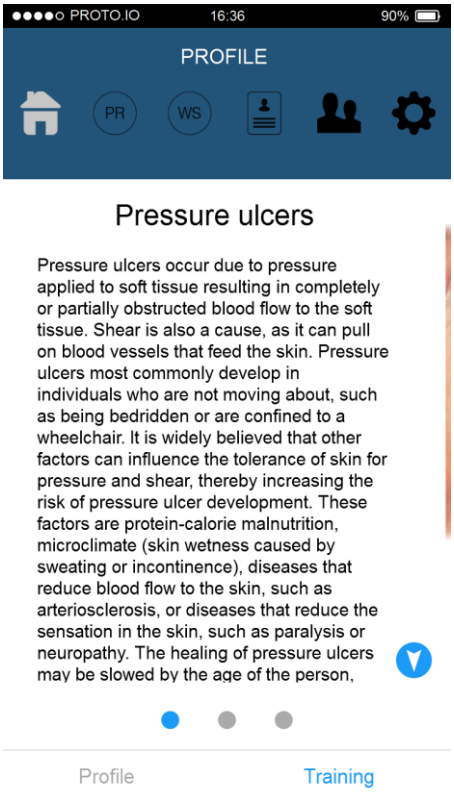

PROTO.IO 16:40 90%
Back
APP NAME
Social network
RYAN YOUNG
Atlanta, GA
CHEER
FRIEND
PRESSURE RELIEFS
4
total
6
till goal
WEIGHT SHIFTS
12
total
8
till goal
Leave a message!
SUBMIT
Dashboard
Profile
Friends

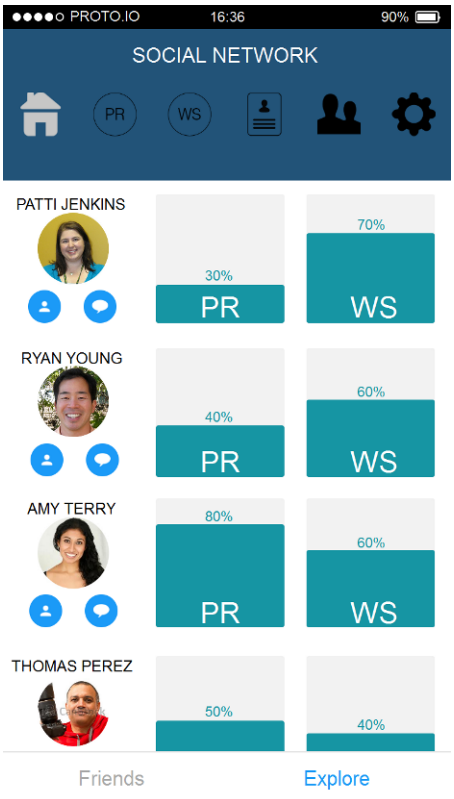

PROTO.IO
16:40
90%
Back
APP NAME
Settings
Text size
Increase or decrease font size
Alert settings
Alert every
minutes
Vibrate alert on or off
If on, phone will vibrate when time to perform pressure relief
Message alert on or off
If on, phone will send a message when time to perform pressure relief
Paired devices
Pressure mat
Apple watch
Dashboard
Profile
Friends

Design D-v2

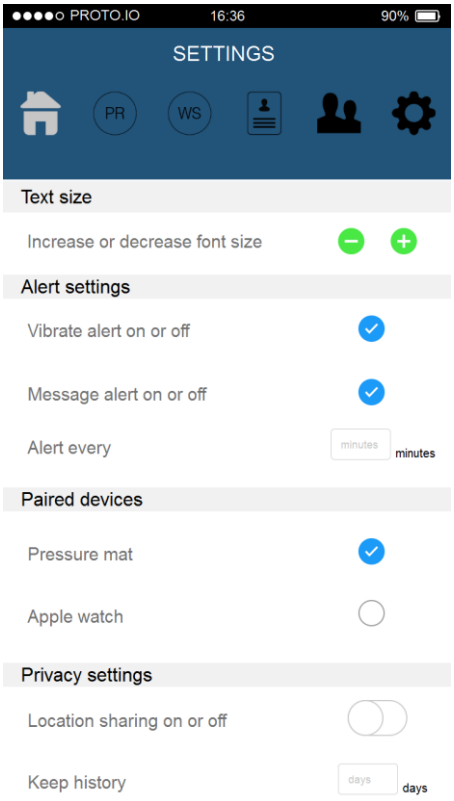

PROTO.IO 16:36 90%
APP NAME
PR
WS
PR
4 Total pressure reliefs
3 Till goal
Wednesday, May 2, 2012
12:15pm
WS
8 Total weight shifts
12 Till goal
PROTO.IO 16:36 90%
PRESSURE RELIEFS
PR
WS
4/29 4/30 5/1 5/2
WEDNESDAY
3
1
4
AM TOTAL
0
PM TOTAL
Goal 7
Total 4
Time since last relief 45m
Average 1/hr
Day view
Month view
PROTO.IO 16:36 90%
PRESSURE RELIEFS
PR
WS
May
Su Mo Tu We Th Fr Sa
Day view
Month view
PROTO.IO 16:36 90%
WEIGHT SHIFTS
PR
WS
4/29 4/30 5/1 5/2
WEDNESDAY
1
5
2
8
AM TOTAL
0
PM TOTAL
Goal 20
Total 8
Time since last shift 45m
Average 2.1/hr
Day view
Month view


PROTO.IO 16:36 90%
PROFILE
PR
WS
Add a photo
Your name
Location
0 friends
4 Cheers
0 messages
Set your pressure relief goal
Goal
Set your weight shift goal
Goal
Profile
Training


PROTO.IO 16:36 90%
PROFILE
PR
WS
Pressure ulcers
Pressure ulcers occur due to pressure applied to soft tissue resulting in completely or partially obstructed blood flow to the soft tissue. Shear is also a cause, as it can pull on blood vessels that feed the skin. Pressure ulcers most commonly develop in individuals who are not moving about, such as being bedridden or are confined to a wheelchair. It is widely believed that other factors can influence the tolerance of skin for pressure and shear, thereby increasing the risk of pressure ulcer development. These factors are protein-calorie malnutrition, microclimate (skin wetness caused by sweating or incontinence), diseases that reduce blood flow to the skin, such as arteriosclerosis, or diseases that reduce the sensation in the skin, such as paralysis or neuropathy. The healing of pressure ulcers may be slowed by the age of the person,
Profile
Training


PROTO.IO 16:36 90%
SOCIAL NETWORK
PR
WS
PATTI JENKINS
30%
PR
70%
WS
RYAN YOUNG
40%
PR
60%
WS
AMY TERRY
80%
PR
60%
WS
THOMAS PEREZ
50%
40%
Friends
Explore


PROTO.IO 16:36 90%
Back
SOCIAL NETWORK
PR
WS
Wednesday, May 2, 2012
Atlanta, GA
40%
PR
40 %
4 total
6 till goal
60%
WS
60 %
12 total
8 till goal


PROTO.IO
16:36
90%
SETTINGS
PR
WS
Text size
Increase or decrease font size
Alert settings
Vibrate alert on or off
Message alert on or off
Alert every
minutes
minutes
Paired devices
Pressure mat
Apple watch
Privacy settings
Location sharing on or off
Keep history
days
days

APPENDIX I

Usability tasks

Time is started at each number and restarted after each task is completed.
Bold tasks are when time will be reported when completed.

	Completed?	
	Yes/Time	No
1. From home screen		
a. Go to screen for pressure reliefs.		
b. Check history for two days before.		
c. **State how many pressure reliefs were done that day**	☐	☐
d. Check data within a two-hour span during the day.		
e. **State how many pressure reliefs were done between 5pm – 7pm**	☐	☐
f. **Did you meet your goal?**	☐	☐
g. Check the week/month view.		
h. **How many times did you miss your goal in the past 7 days?**	☐	☐
i. Go back to home screen.		
2. From home screen		
a. Go to screen for weight shifts		
b. Check history for last Thursday.		
c. **State how many weight shifts were done that day**	☐	☐
d. Go to current day		
e. **State time since last weight shift**	☐	☐
f. **State how many weight shifts were done for that day so far**	☐	☐
3. From weight shift screen		
a. Go to the social network page		
b. Find the person named "Ryan"		
c. Check how many weight shifts they have done today	☐	☐
d. Comment on their status	☐	☐
e. Go back to the Home screen		
4. From home screen		
a. Find the training information on this app		
b. **Watch a video on forward leaning pressure relief**	☐	☐
c. Go to pressure ulcers information page		
d. **Name one fact about pressure ulcers**	☐	☐
5. Go to personal profile page		
a. Change the default name	☐	☐
b. Go to the setting a goal page		
c. Set a goal to perform 20 pressure reliefs today	☐	☐
6. Return to home screen		

Constructs for user survey

Construct	Description
Reduction	The app has unnecessary steps to use certain functions The app has difficult steps to use certain functions The app has functions I don't want
Prioritizing	The app provides important information on the home screen The app displays important functions on the home screen Commonly used functions are easy to get to
Organization	The app shows menu categories systematically The app provides content systematically Information on the app is well-structured and organized
Integration	The app groups similar menu items in the same category The app allows access to certain menus in one step Menus and functions are grouped in logical order
Satisfaction	Using the app is a satisfactory experience I am satisfied with the functions of this app I am satisfied with the information this app displays
Usability	The app provides an easy-to-use interface The app provides an attractive user interface The app easily performs the functions I want it to

Second survey

Name of participant _____

1.	The app has unnecessary steps to use certain functions	Disagree	Agree
2.	The app has difficult steps to use certain functions	Disagree	Agree
3.	The app has functions I don't want	Disagree	Agree
4.	The app provides important information on the home screen	Disagree	Agree
5.	The app displays important functions on the home screen	Disagree	Agree
6.	Commonly used functions are easy to get to	Disagree	Agree
7.	The app shows menu categories systematically	Disagree	Agree
8.	The app provides content systematically	Disagree	Agree
9.	Information on the app is well-structured and organized	Disagree	Agree
10.	The app groups similar menu items in the same category	Disagree	Agree
11.	The app allows access to certain menus in one step	Disagree	Agree
12.	Menus and functions are grouped in logical order	Disagree	Agree
13.	Using the app is a satisfactory experience	Disagree	Agree
14.	I am satisfied with the functions of this app	Disagree	Agree
15.	I am satisfied with the information this app displays	Disagree	Agree
16.	The app provides an easy-to-use interface	Disagree	Agree
17.	The app provides an attractive user interface	Disagree	Agree
18.	The app easily performs the functions I want it to	Disagree	Agree

APPENDIX J

Usability test results

Testing effectiveness: non-successful if X is in cell.
Testing efficiency: measured in times in seconds

	Subject	MH		WC		KD		SG		ML	
	Test #	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2
	Prototype	D-v2	A-v2	A-v2	D-v2	A-v2	D-v2	D-v2	A-v2	A-v2	D-v2
	Task and time completed										
1c	State how many pressure reliefs were done that day	58.72	22.04	15.82	13.47	17.32	13.87	20.25	15.33	44.38	22.45
1e	State how many pressure reliefs were done between 4pm – 6pm	X	15.1	27.04	26.46	33.59	X	X	37.77	41.4	X
1f	Did you meet your goal	6.34	15.83	12.91	9.73	7.76	6.61	7.35	19.94	13.55	10.73
1h	How many times did you miss your goal in the past 7 days?	45.96	31.57	13.35	32.21	13.03	33.92	X	18.13	X	X
2c	State how many weight shifts were done that day	35.32	16.68	16.07	17.81	21.71	26.82	22.83	20.13	1.04.09	39.69
2e	State time since last weight shift	10.64	13.85	11.65	10.83	17.92	8.76	16.71	15.67	14.15	X*
2f	State how many weight shifts were done for that day so far	7.29	4.9	4.79	4.41	4.95	4.03	5.07	6.98	4.04	14.41
3c	Check how many weight shifts they have done today	31.07	26.7	29.7	16.8	16.56	16.05	21.63	14.96	24.29	25.07
3d	Comment on their status	11.48	7.24	6.14	7.72	8.41	5.36	6.8	4.07	X*	8.24
4b	Watch a video on forward leaning pressure relief	43.28	21.11	36.47	18.35	30.16	16.15	39.68	28.81	1.58.24	53.36
4d	Name one fact about pressure ulcers	5.57	22.02	8.43	3.97	18.68	13.73	9.07	8.27	11.01	13.17
5a	Change the default name	11.87	5.61	10.77	15.68	11.26	6.68	44.3	7.42	11.39	27.52
5c	Set a goal to perform 20 pressure reliefs today	13.39	5.11	10.81	11.4	11.34	6.13	17.85	7.74	14.59	26.77

	Subject	CE		DK		KS		PA		GC	
	Test #	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2
	Prototype	D-v2	A-v2	A-v2	D-v2	D-v2	A-v2	A-v2	D-v2	D-v2	A-v2
	Task and time completed										
1c	State how many pressure reliefs were done that day	16.32	10.95	19.71	19.87	50.62	23.42	28.02	19.31	38.1	24.01
1e	State how many pressure reliefs were done between 4pm – 6pm	X	X	30.61	43.09	X	52.45	31.78	1.07.54	X	23.61
1f	Did you meet your goal	5.25	3.95	8.77	5.38	4.9	8.32	19.37	5.14	20.59	5.61
1h	How many times did you miss your goal in the past 7 days?	25.63	4.59	12.36	1.23.95	X	17.43	11.78	40.57	22.16	26.86
2c	State how many weight shifts were done that day	25.8	18.07	25.97	22.74	29.21	45.32	22.16	20.92	22.05	36.56
2e	State time since last weight shift	8.31	7.02	22.45	16.94	20.84	13.52	13.92	37.12	10.85	9.63
2f	State how many weight shifts were done for that day so far	3.4	2.89	4.25	3.82	4.36	4.78	4.58	7.48	8.85	3.77
3c	Check how many weight shifts they have done today	13.41	12.97	23.07	26.64	55.48	20.37	17.01	16.31	21.86	15.81
3d	Comment on their status	12.08	3.71	6.97	4.69	10.01	5.59	4.01	5.59	8.51	3.17
4b	Watch a video on forward leaning pressure relief	38.28	16.21	25	1.22.68	49.95	48.58	44.08	20.84	1.08.91	17.84
4d	Name one fact about pressure ulcers	11.58	4.46	24.85	10.61	15.02	5.67	20.2	7.46	6.2	11.19
5a	Change the default name	15.43	7.22	12.69	7.3	17.56	7.09	11.62	8.97	26.26	6.28
5c	Set a goal to perform 20 pressure reliefs today	8.33	6.09	7.38	7.52	6.59	5.43	5.84	5.29	6.01	5.04

Satisfaction survey: used to see how respondent reacted to each design

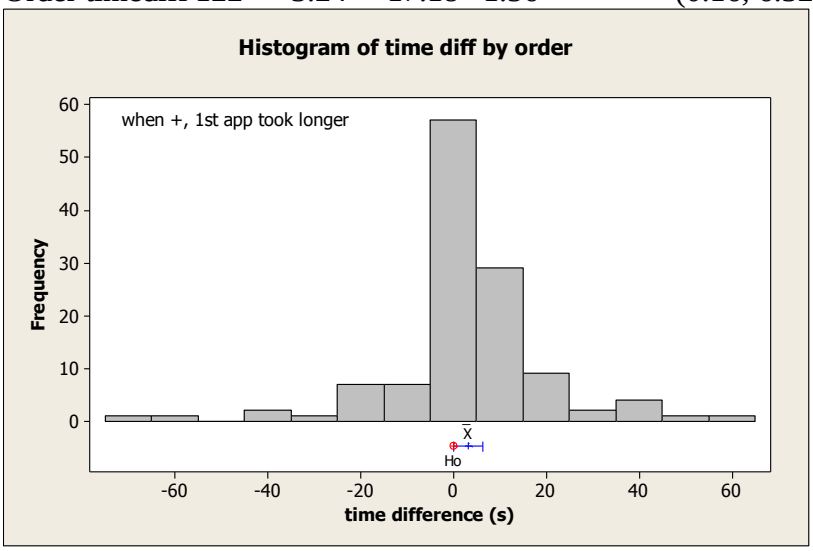
Subject		MH		Wc		KD		SG		ML	
Test #		#1	#2	#1	#2	#1	#2	#1	#2	#1	#2
Prototype	*Desired*	D-v2	A-v2	A-v2	D-v2	A-v2	D-v2	D-v2	A-v2	A-v2	D-v2
Question	*response*										
1. The app has unnecessary steps to use certain functions	agree	agree	disagree	disagree	disagree	agree	agree	disagree	agree	disagree	agree
2. The app has difficult steps to use certain functions	disagree	disagree	disagree	disagree	disagree	disagree	agree	disagree	agree	disagree	disagree
3. The app has functions I don't want	disagree	disagree	disagree	disagree	disagree	agree	agree	agree	agree	agree	agree
4. The app provides important information on the home screen	agree	agree	agree	agree	agree	agree	agree	agree	agree	disagree	agree
5. The app displays important functions on the home screen	agree	agree	agree	agree	agree	agree	agree	agree	agree	disagree	disagree
6. Commonly used functions are easy to get to	agree	agree	agree	agree	agree	agree	agree	agree	agree	agree	agree
7. The app shows menu categories systematically	agree	disagree	disagree	agree	agree	disagree	agree	disagree	agree	agree	disagree
8. The app provides content systematically	agree	disagree	disagree	agree	agree	agree	agree	agree	agree	agree	agree
9. Information on the app is well-structured and organized	agree	disagree	agree	agree	agree	agree	agree	agree	agree	disagree	agree
10. The app groups similar menu items in the same category	agree	agree	agree	agree	agree	agree	agree	agree	agree	agree	disagree
11. The app allows access to certain menus in one step	agree	agree	agree	agree	agree	agree	agree	agree	agree	agree	disagree
12. Menus and functions are grouped in logical order	agree	agree	agree	agree	agree	agree	agree	disagree	agree	disagree	agree
13. Using the app is a satisfactory experience	agree	agree	agree	agree	agree	agree	agree	agree	agree	agree	agree
14. I am satisfied with the functions of this app	agree	agree	agree	agree	agree	agree	disagree	agree	agree	agree	agree
15. I am satisfied with the information this app displays	agree	agree	agree	agree	agree	agree	disagree	agree	agree	disagree	agree
16. The app provides an easy-to-use interface	agree	disagree	agree	agree	agree	agree	disagree	agree	agree	agree	agree
17. The app provides an attractive user interface	agree	agree	disagree	agree	agree	agree	agree	agree	disagree	disagree	agree
18. The app easily performs the functions I want it to	agree	agree	agree	agree	agree	agree	agree	agree	agree	agree	agree
Total undesired answers per person per test		4	4	1	1	2	5	4	3	8	5

Subject	CE		DK		KS		PA		GC		
Test #	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	
Prototype	D-v2	A-v2	A-v2	D-v2	D-v2	A-v2	A-v2	D-v2	D-v2	A-v2	**Total undesired answers per task**
Question											
1. The app has unnecessary steps to use certain functions	disagree	disagree	disagree	disagree	disagree	disagree	agree	agree	disagree	disagree	13
2. The app has difficult steps to use certain functions	agree	agree	disagree	disagree	agree	disagree	disagree	disagree	agree	disagree	6
3. The app has functions I don't want	agree	disagree	disagree	disagree	disagree	disagree	disagree	disagree	disagree	disagree	7
4. The app provides important information on the home screen	agree	agree	agree	agree	agree	agree	agree	agree	agree	agree	1
5. The app displays important functions on the home screen	agree	agree	agree	agree	agree	agree	agree	agree	agree	agree	2
6. Commonly used functions are easy to get to	agree	agree	agree	agree	agree	agree	agree	agree	agree	agree	0
7. The app shows menu categories systematically	disagree	agree	agree	agree	agree	agree	agree	agree	agree	agree	6
8. The app provides content systematically	disagree	disagree	agree	agree	agree	agree	agree	agree	agree	agree	4
9. Information on the app is well-structured and organized	disagree	agree	agree	disagree	agree	agree	agree	agree	agree	agree	4
10. The app groups similar menu items in the same category	agree	agree	agree	agree	disagree	agree	disagree	agree	agree	agree	3
11. The app allows access to certain menus in one step	agree	agree	agree	agree	disagree	agree	agree	agree	disagree	agree	3
12. Menus and functions are grouped in logical order	agree	agree	agree	agree	agree	agree	agree	agree	agree	agree	2
13. Using the app is a satisfactory experience	disagree	agree	agree	disagree	disagree	agree	agree	agree	agree	agree	3
14. I am satisfied with the functions of this app	agree	agree	agree	agree	disagree	agree	agree	disagree	agree	agree	3
15. I am satisfied with the information this app displays	agree	agree	agree	agree	agree	agree	agree	agree	disagree	agree	3
16. The app provides an easy-to-use interface	agree	agree	agree	disagree	agree	agree	agree	agree	agree	agree	3
17. The app provides an attractive user interface	agree	agree	agree	agree	agree	agree	agree	agree	agree	agree	3
18. The app easily performs the functions I want it to	agree	agree	agree	agree	agree	agree	agree	agree	agree	agree	0
Total undesired answers per person	7	3	1	4	6	1	1	1	4	1	

Assessing order effect

Calculating time differences between 1st and 2nd app

Variable	N	Mean	StDev	SE Mean	95% CI		T	P
Order timediff	122	3.24	17.18	1.56	(0.16, 6.32)	2.08	0.039	

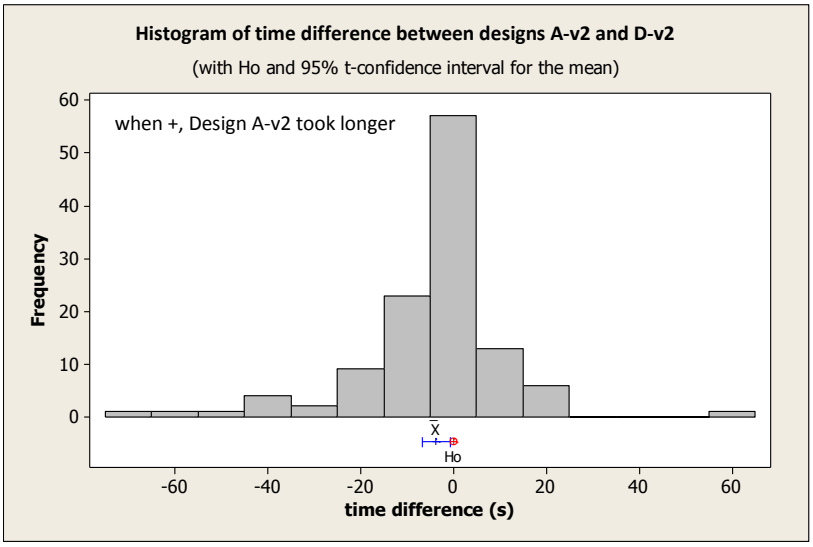


Assessing difference in apps

Time difference between design A-v2 and design D-v2

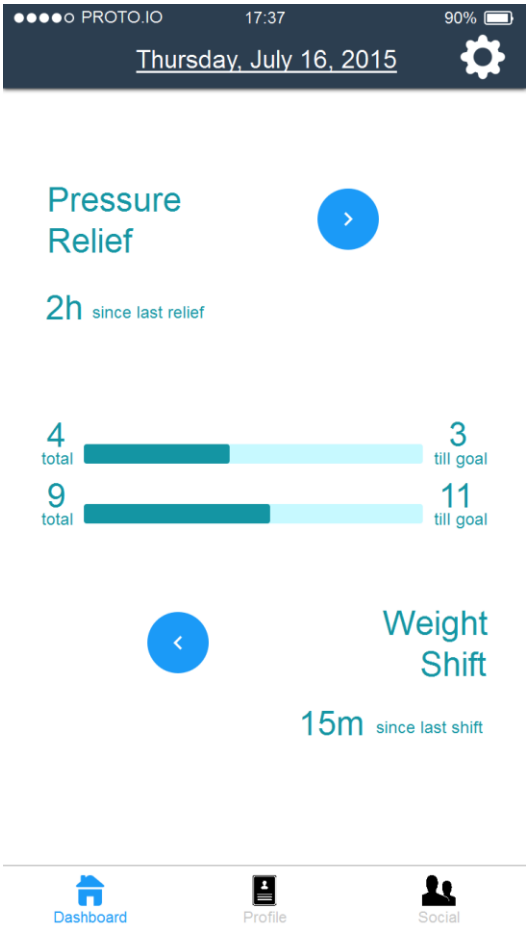
Variable	N	Mean	StDev	SE Mean	95% CI		T	P
timediff				1.49	(-6.67, -0.76)	-2.49	0.014	

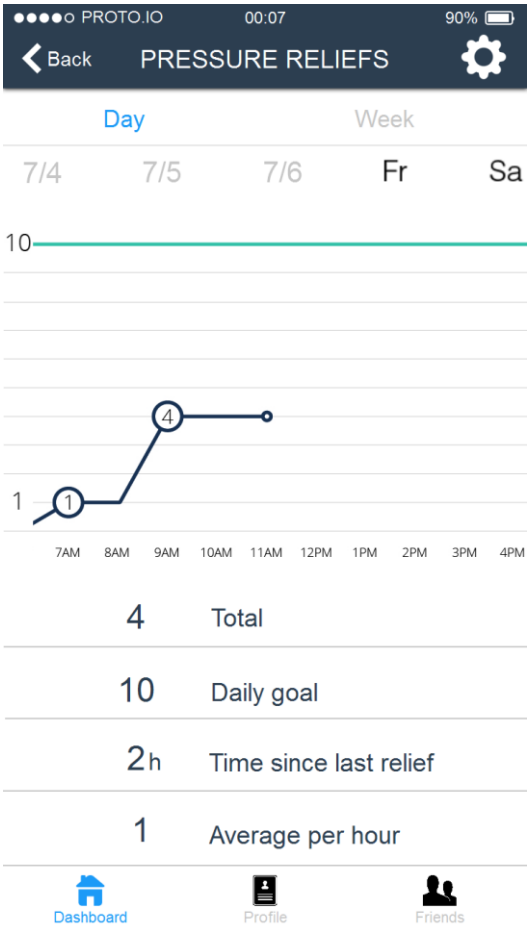
when +, Design A-v2 took longer

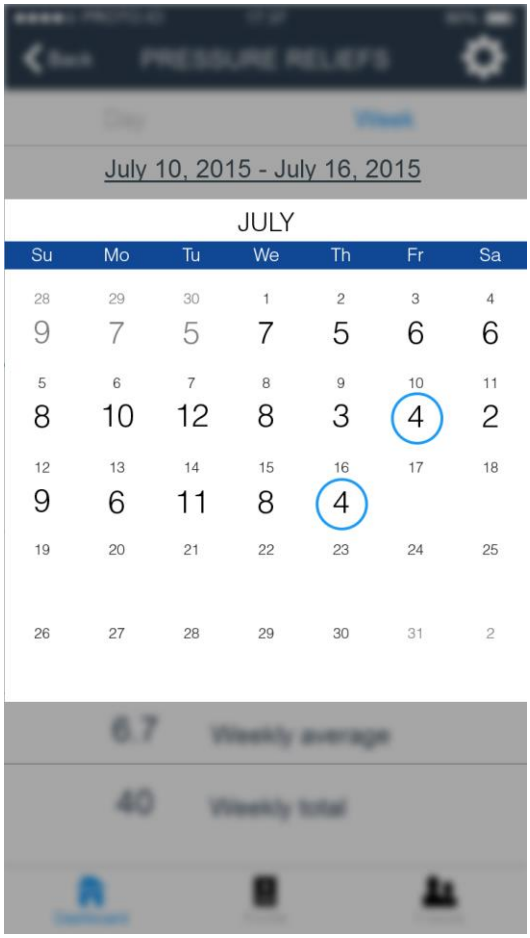


APPENDIX K

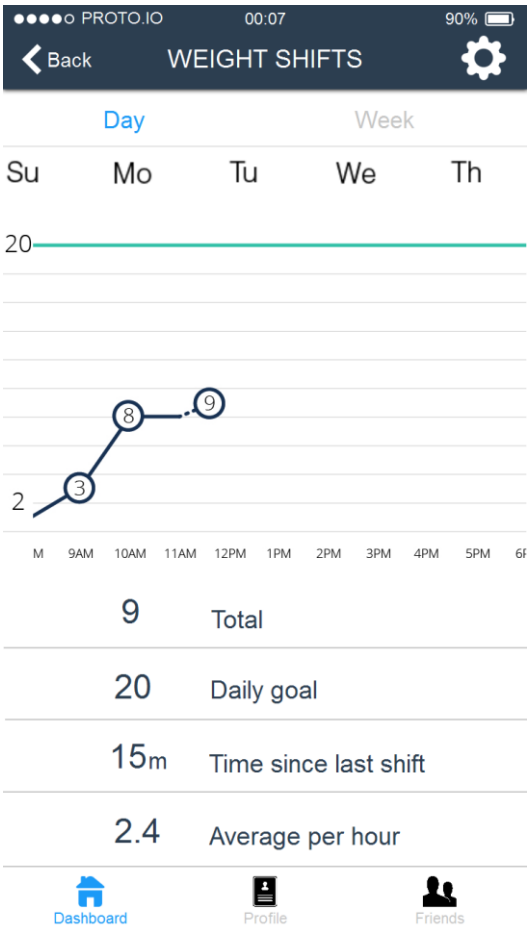
Final Designs

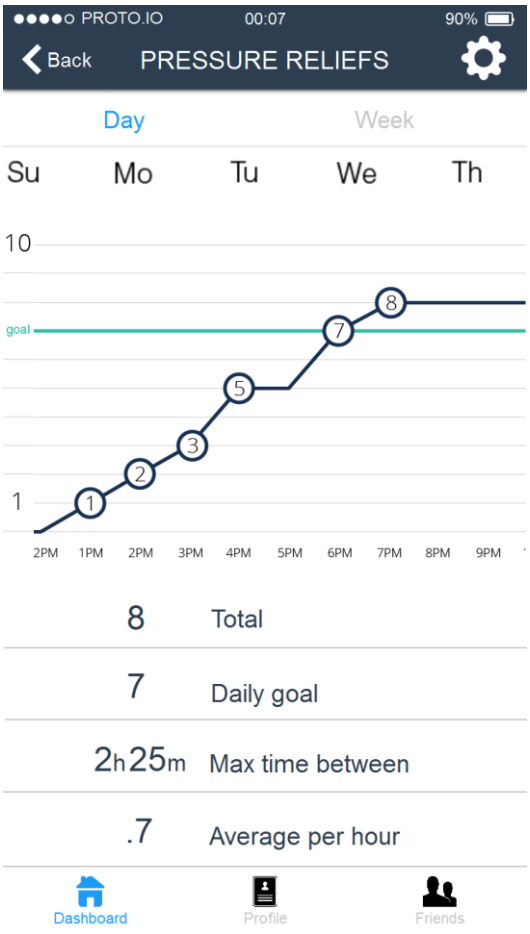


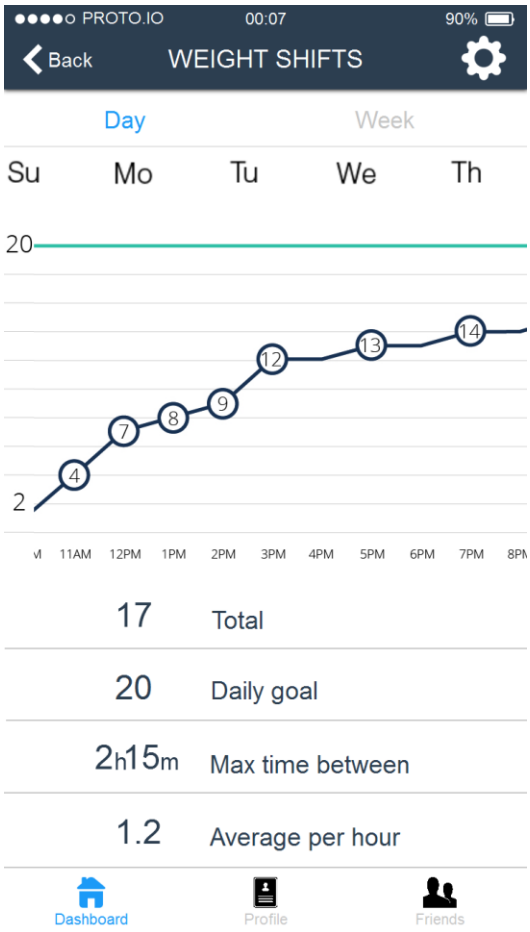


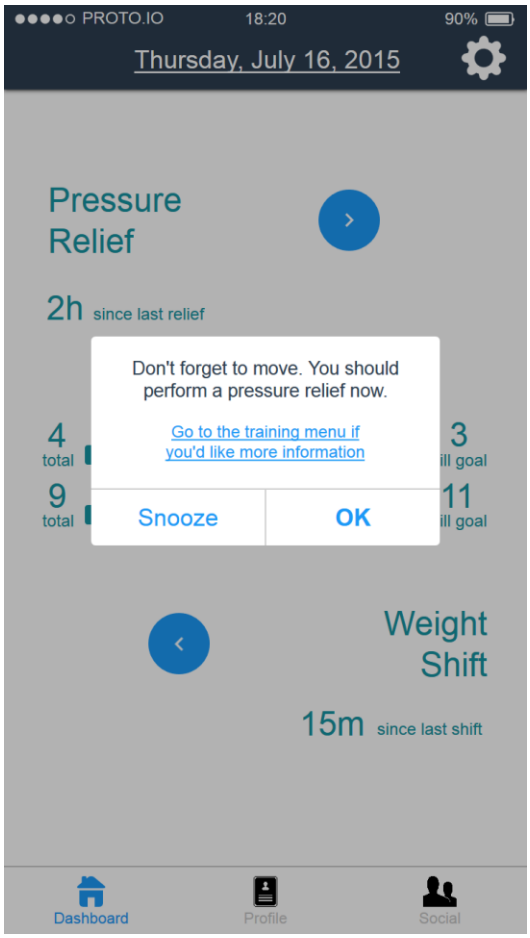

July 10, 2015 - July 16, 2015
JULY
Su Mo Tu We Th Fr Sa

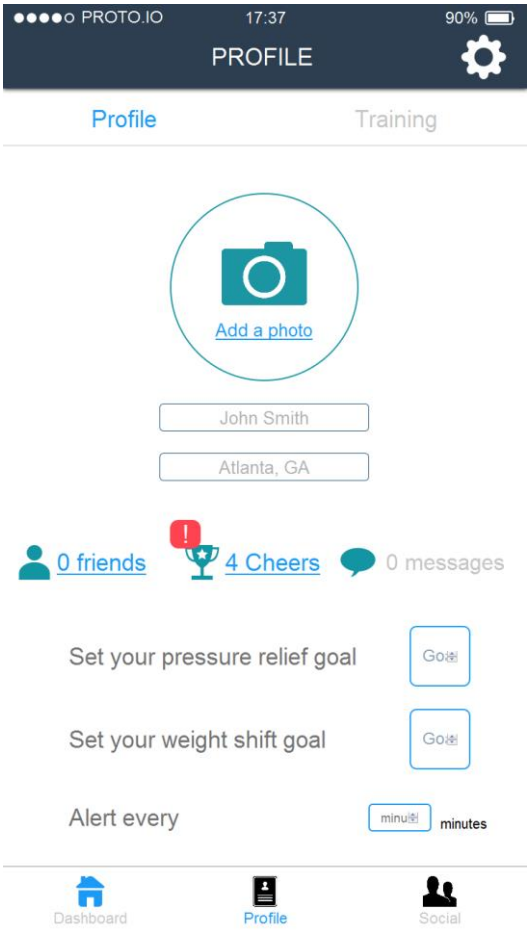

PROTO.IO 17:37 90%
Back
PRESSURE RELIEFS
Day
Week
July 10, 2015 - July 16, 2015
goal
Fr Sa Su Mo Tu We Th
7 Average daily goal
6.7 Weekly average
40 Weekly total
Dashboard
Profile
Friends

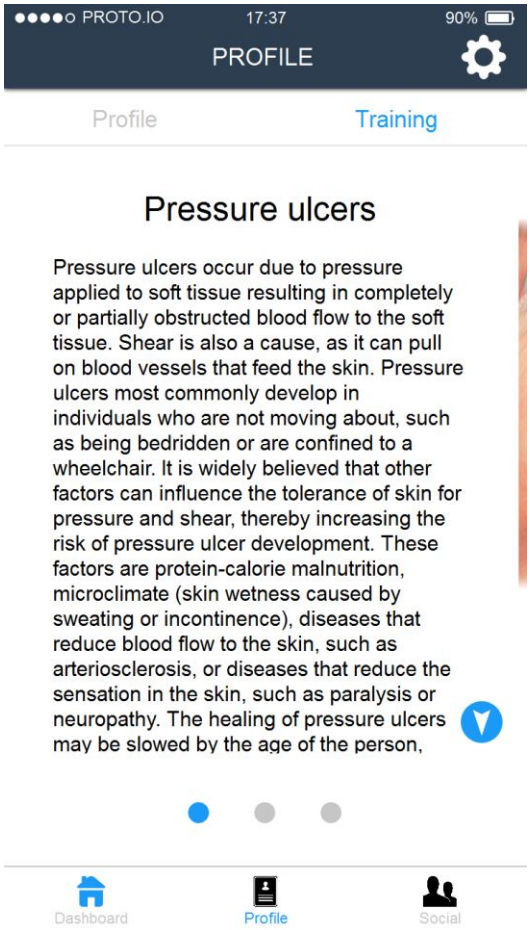

PROTO.IO 00:07 90%
Back
WEIGHT SHIFTS
Day
Week
Su Mo Tu We Th
20
2
M 9AM 10AM 11AM 12PM 1PM 2PM 3PM 4PM 5PM
9 Total
20 Daily goal
15m Time since last shift
2.4 Average per hour
Dashboard
Profile
Friends

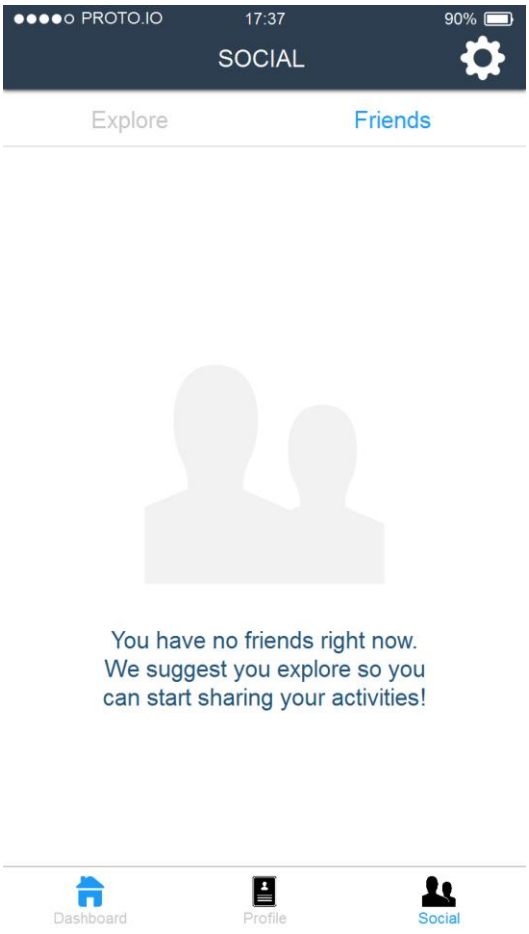

PROTO.IO 00:07 90%
Back
PRESSURE RELIEFS
Day
Week
Su Mo Tu We Th
10
goal
1
2PM 1PM 2PM 3PM 4PM 5PM 6PM 7PM 8PM 9PM
8 Total
7 Daily goal
2h25m Max time between
.7 Average per hour
Dashboard
Profile
Friends

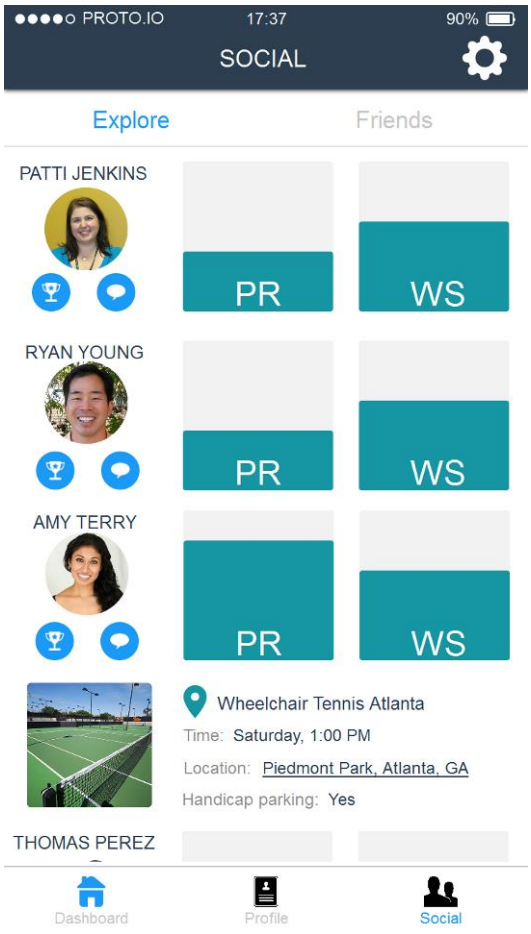

PROTO.IO 00:07 90%
Back
WEIGHT SHIFTS
Day
Week
Su Mo Tu We Th
20
2
4 7 8 9 12 13 14
11AM 12PM 1PM 2PM 3PM 4PM 5PM 6PM 7PM 8PM
17 Total
20 Daily goal
2h15m Max time between
1.2 Average per hour
Dashboard
Profile
Friends

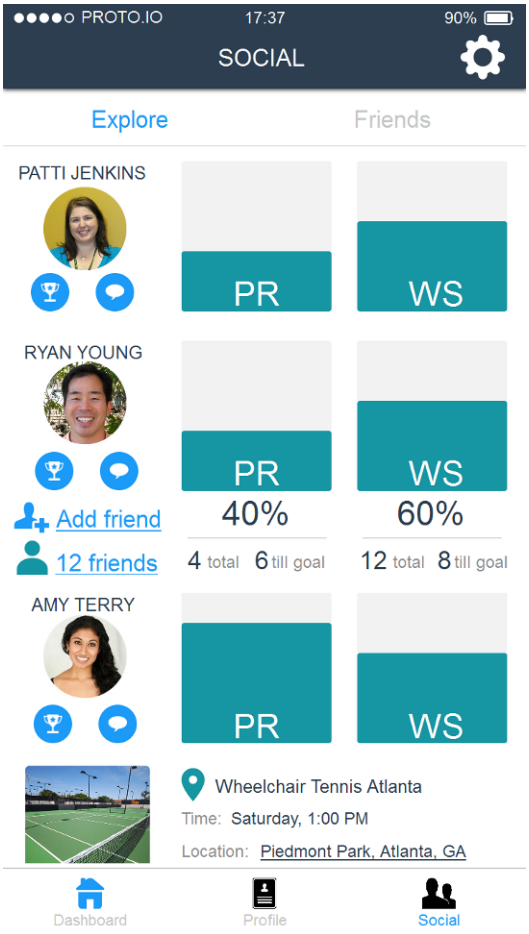

PROTO.IO 18:20 90%
Thursday, July 16, 2015
Pressure Relief
2h since last relief
Don't forget to move. You should perform a pressure relief now.
Go to the training menu if you'd like more information
Snooze
OK
4 total
3 till goal
9 total
11 till goal
Weight Shift
15m since last shift
Dashboard
Profile
Social

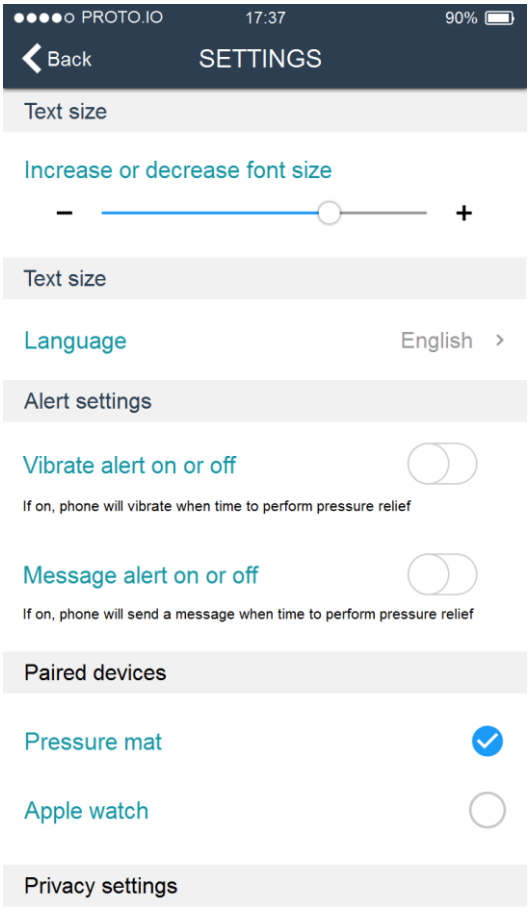

PROTO.IO 17:37 90%
PROFILE
Profile
Training
Add a photo
John Smith
Atlanta, GA
0 friends
4 Cheers
0 messages
Set your pressure relief goal
Go
Set your weight shift goal
Go
Alert every
minutes
Dashboard
Profile
Social


PROTO.IO 17:37 90%
PROFILE
Profile
Training
Pressure ulcers
Pressure ulcers occur due to pressure applied to soft tissue resulting in completely or partially obstructed blood flow to the soft tissue. Shear is also a cause, as it can pull on blood vessels that feed the skin. Pressure ulcers most commonly develop in individuals who are not moving about, such as being bedridden or are confined to a wheelchair. It is widely believed that other factors can influence the tolerance of skin for pressure and shear, thereby increasing the risk of pressure ulcer development. These factors are protein-calorie malnutrition, microclimate (skin wetness caused by sweating or incontinence), diseases that reduce blood flow to the skin, such as arteriosclerosis, or diseases that reduce the sensation in the skin, such as paralysis or neuropathy. The healing of pressure ulcers may be slowed by the age of the person,
Dashboard
Profile
Social


PROTO.IO
17:37
90%
SOCIAL
Explore
Friends
You have no friends right now.
We suggest you explore so you
can start sharing your activities!
Dashboard
Profile
Social


PROTO.IO
17:37
90%
SOCIAL
Explore
Friends
PATTI JENKINS
PR
WS
RYAN YOUNG
PR
WS
AMY TERRY
PR
WS
Wheelchair Tennis Atlanta
Time: Saturday, 1:00 PM
Location: Piedmont Park, Atlanta, GA
Handicap parking: Yes
THOMAS PEREZ
Dashboard
Profile
Social


PROTO.IO
17:37
90%
SOCIAL
Explore
Friends
PATTI JENKINS
PR
WS
RYAN YOUNG
PR
WS
Add friend
12 friends
40%
4 total 6 till goal
60%
12 total 8 till goal
AMY TERRY
PR
WS
Wheelchair Tennis Atlanta
Time: Saturday, 1:00 PM
Location: Piedmont Park, Atlanta, GA
Dashboard
Profile
Social


PROTO.IO
17:37
90%
Back
SETTINGS
Text size
Increase or decrease font size
Text size
Language
English
Alert settings
Vibrate alert on or off
If on, phone will vibrate when time to perform pressure relief
Message alert on or off
If on, phone will send a message when time to perform pressure relief
Paired devices
Pressure mat
Apple watch
Privacy settings

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